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GEOLOGICAL SURVEY OF ALABAMA

WALTER B. JONES, STATE GEOLOGIST

BULLETIN 55

ALABAMA SHALES AND FIRE CLAYS

By

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and

Lyman D. Toulmin

UNIVERSITY, ALABAMA

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LETTER OF TRANSMITTAL

University, Alabama
July 24, 1945

Honorable Chauncey Sparks
Governor of Alabama
Montgomery, Alabama

Sir:

I have the honor to transmit herewith the manuscript of a report on "Alabama Shales and Fire Clays", by Thomas N. McVay and Lyman D. Toulmin. It is requested that this be printed as Bulletin 55 of the Geological Survey of Alabama.

Respectfully,

WALTER B. JONES
State Geologist

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ALABAMA SHALES AND FIRE CLAYS

By

THOMAS N. McVAY and LYMAN D. TOULMIN

ABSTRACT

The geologic relations of the shales of Alabama are discussed and a map showing the areal distribution of the important shale formations is included in the report. One hundred and four samples of shale and fire clay from all parts of Alabama were collected by the Geological Survey of Alabama and tested by the Department of Ceramics of the University of Alabama. The testing procedure and the character of the raw samples and their firing behavior are described. A map showing places where samples were taken and tables showing results of tests are included in the report. Chemical analyses of six selected samples are given.

INTRODUCTION

Purpose and Scope of Investigation

This bulletin on Alabama shales is the result of an investigation conducted jointly by the Geological Survey of Alabama and the Department of Ceramics of the University of Alabama. The Geological Survey and the Department of Ceramics under the cooperative arrangement collected and tested one hundred and four samples of shale and fire clay from all sections of the state. A general description of the geological formations and a more detailed description of the character of the deposits sampled and the results of the tests are given in the report. The Geological Survey assumed the responsibility of collecting representative samples and obtaining information concerning each formation and deposit sampled. The Department of Ceramics performed all necessary tests and compiled the results. The field work was done by the Geological Survey during the winter of 1943-1944, and the samples collected were sent to the laboratories of the Department of Ceramics where they were tested under the supervision of the senior author. The testing and burning of samples was completed in September, 1944.

Chemical analyses of six selected samples were made by Emerson Poste of Chattanooga, Tennessee.

The samples of shale tested and described in this report were collected by the authors from exposures of the formations in road cuts and mining pits. Where possible, samples were gathered from widely separated exposures of each important formation in order that variations in properties of samples from different outcrops of the same geological formation could be determined and some idea obtained of the limits of variation. Shale deposits are not uniform and samples from other localities may show some variation from results given in the report. Several samples were taken from weathered outcrops and considerable difference in properties therefore can be expected in samples from unweathered bedrock in the same locality. No prospecting was attempted. Grab samples aggregating 50 pounds in weight were taken at intervals along the outcrop at each locality in order that the composite sample would be representative.

The purpose of this work has been to obtain information on the distribution, properties, and possible uses of the shales of Alabama. No report on Alabama shales has been published heretofore. Clays of Alabama have been described in Bulletin 6 of the Geological Survey of Alabama which was published in 1900. Later descriptions of Alabama clays are included in Bulletin 901 of the U. S. Geological Survey entitled "Clay investigations in the Southern States, 1934-35", which was published in 1940. Clays and shales are used similarly in the manufacture of ceramic products, and the present report will help to complete the information already available on these Alabama resources.

Acknowledgments

The writers wish to acknowledge the courteous aid received from many persons throughout the state during the course of the investigation. Managers and superintendents of brick, tile and sewer pipe plants aided in the work by furnishing samples of shale and clay used in the plants. Dr. Stewart J. Lloyd, Dean of the School of Chemistry, Metallurgy, and Ceramics of the University of Alabama, and Assistant State Geologist, read the manuscript and made valuable suggestions, and also assisted in the collection of some of the samples. Mr. Philip La Moreaux, Junior Geologist

of the Ground Water Division of the U. S. Geological Survey, rendered invaluable aid by assisting in the collection of a large number of the samples. Mr. L. H. Berkelhamer determined the minerals present in some of the samples by means of differential thermal analysis. Mr. James Tiller, Mr. Preston Cunningham, and Mr. John Cunningham prepared the samples for testing and made most of the firing tests. The cut of the extrusion machine was obtained through the courtesy of International Clay Machinery Company.

The Department of Ceramics received an allotment from the University Research Fund which covered the expense of the part of the investigation undertaken by the Department The remainder of the expense of the work, mainly that incident to field work and to publication of the report, was borne by the Geological Survey of Alabama.

Definition of Shale

Shale is a thinly bedded or laminated sediment composed predominantly of extremely fine particles of clay grade. It is a variety of sedimentary rock which has resulted from the consolidation of bedded silts, muds, and clays. A typical shale has the property of splitting or cleaving easily along the planes of lamination or bedding. The distinction between shale and clay is made principally on this physical property of splitting readily along bedding planes and the term shale is restricted to such deposits of thinly bedded or laminated clays hardened by compaction or consolidation. Shales may be of either fresh water or marine origin. Like clay, shale is an earthy aggregate containing hydrous silicates of alumina. Most shales are plastic when sufficiently pulverized and wetted, and become hard when burned.

Shale and slate are often confused. Slate is a metamorphic rock, formed from fine-grained deposits such as shales and mudstones, which has been so metamorphosed by pressure that it splits or cleaves readily along planes independent of the original bedding. Fine grinding produces little or no plasticity. Further metamorphism of slate produces a phyllite which is a compact lustrous fissile or foliated rock resembling slate in appearance but characterized by the development of fine mica or sericite along the planes of foliation. The sericite is formed under metamorphic conditions and a phyllite is not to be confused with a micaceous shale in which the flakes of mica have been deposited from suspension along with other products of rock decay which make up the shale deposit.

More intense metamorphism produces a schist in which the growth of metamorphic minerals has continued until they are visible to the naked eye. These minerals, principally mica, give the rock a foliated character owing to their parallel arrangement.

Origin of Shale

Shale is of sedimentary origin, the component material having been derived from pre-existing rock such as clay or shale or, if traced back to its ultimate source, some form of igneous rock. The processes involved in the formation of shale are weathering, including mechanical disintegration and chemical decomposition of the source rocks under the influence of the weather, transportation and deposition of the products of weathering, and subsequent consolidation of the deposited material.

The material composing shale deposits consists of clay minerals and other fine rock debris. Clay minerals, consisting of hydrous silicates of aluminum such as kaolinite and related minerals, are secondary in origin, having been formed originally by the weathering of silicate minerals composing the crystalline rocks.

The rock particles and clay minerals resulting from weathering are transported by running water which acts as a sorting agent separating particles of different size and specific gravity. Streams having a high velocity carry both clay and sand particles. Separation occurs at places where the velocity is checked, allowing the larger particles to settle out. Thus sand bars may be formed in the channels of streams and deposits of silt along the flood plains. Large deposits of clay free from sand may accumulate in large areas of quiet water into which streams carrying clay particles empty. The body of water may be a fresh water lake, a brackish water estuary, a lagoon, or the sea.

After the clay has been deposited, it undergoes modifications in many ways. It may be buried under hundreds of feet of additional sediments and thus consolidated to form shale by compaction resulting from this weight. Clay and silt particles pack tightly together leaving extremely small voids. Colloidal clay may act as a binder. The density of shale is increased and much of the mechanically enclosed water is eliminated during consolidation.

Geologic earth movements may lead to further modification of the deposit. Simple uplift may bring the deposit into the zone of ground water action or into the zone of leaching, with attendant chemical and physical alteration of the deposit, or compressive earth movements causing folding or faulting may produce metamorphism of the deposit resulting in the formation of slate or phyllite.

Composition and Classification of Shale

The relative proportions of the mineral constituents of different shales vary within wide limits. Although little is known of the quantitative mineralogical composition of shale, variations in compositions are reflected in chemical analyses: Identification of minerals in shale is difficult owing to the fine state of subdivision of the particles. Analyses of shales of different types are given below.

Analyses of Shales[1]

	1	2	3
SiO_2	58.38	75.24	59.95
Al_2O_3	15.47	10.96	17.99
Fe_2O_3	4.03	4.01	4.62
FeO	2.46		2.61
MgO	2.45	.61	1.49
CaO	3.12	.40	.75
Na_2O	1.31	.51	.28
K_2O	3.25	2.63	2.75
H_2O—)		.62	1.30
)	5.02		
H_2O+)			5.49

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[1] Lamborn, R. E., Austin, C. R., and Schaaf, Downs, Shales and surface clays of Ohio: Ohio Geol. Survey, fourth series, Bull. 39, p. 20, 1938 (1939).

Analysis of Shales—(Con't.)

	1	2	3
TiO_2	.65	.90	1.07
CO_2	2.64	-------	.89
P_2O_5	.17	.15	.17
SO_3	.65	-------	-------
C	.81	-------	.51
MnO	trace	trace	.06
S	-------	-------	.14
FeS_2	-------	-------	-------

1. Average or composite analysis of 78 shales.
(U. S. Geol. Survey, Bull. 770, p. 631, 1924)

2. Pottsville shale, near Wadsworth, Medina County, Ohio.
Analysis by U. S. Bureau of Mines.

3. Average of 35 analyses of shales utilized in the ceramic industry.
Analyses by Downs Schaaf.

Variations in the physical properties of shales are due largely to variations in mineral compositions and to conditions of formation and subsequent alteration of the deposits. Shales may be classified in a simple manner as clay shale, sandy shale, calcareous shale, ferruginous shale, carbonaceous shale, and micaceous shale.

Clay shale is distinguished by a smooth greasy feel owing to the predominance of very fine-grained materials, especially colloidal clay, and low percentage of coarse silt. Gray, greenish gray, buff, and red are the most common colors. The common shale in the Pottsville formation in Alabama is an example of this type.

Sandy or arenaceous shale is characterized by the presence of sand or coarse silt, generally quartz, in noticeable amounts. The colors vary, but light shades of gray, buff, and brown are the most common. Sandy shale beds are present in several formations in Alabama. Examples from this report are samples 84 and 85 from the Weisner formation, sample 71 from the Naheola formation, and sample 73 from the Tuscahoma formation.

Calcareous shale contains a relatively high percentage of calcium carbonate. The calcareous matter may be disseminated throughout the shale in fine particles, or may occur as nodular concretions, as shells of former animal life, or as thin layers along the bedding planes. Calcareous shale is commonly gray in color but where other impurities such as iron and carbon are present in large amounts the color may vary. Sample 104 from the Tuscumbia limestone is an example of a highly calcareous shale.

Ferruginous shale is one containing iron minerals that are conspicuous in the unweathered rock and that are sufficient in amount to produce marked red, brown, or yellowish brown colors on weathering. Iron compounds are present in practically all shales in some amount. Unweathered shale rich in iron-bearing minerals is characteristically gray, greenish gray, or bluish gray in color. Oxidation and hydration of the iron compounds as a result of weathering produces red, buff, and brown colors.

Carbonaceous shale contains sufficient organic matter to give it a dark brown or black color where unweathered. Carbonaceous shale commonly contains iron sulfide either as disseminated grains or as nodular concretions. Sample 41 from the Blocton Coal Mine, is an example of a highly carbonaceous shale.

A micaceous shale is one containing flakes of white mica in conspicuous abundance. Mica is a common constituent of shale and occurs as small scale-like flakes with the flat surfaces parallel to the bedding planes. Micaceous shale is characterized by the bright, shimmering, appearance of the bedding surfaces owing to the high reflection of light from the mica flakes.

GEOLOGICAL RELATIONS OF THE SHALES OF ALABAMA[1]

In this chapter the geologic formations cropping out in Alabama are very briefly reviewed, but the formations containing shale are described a little more fully. For information on the area of outcrop, or distribution, of the formations the reader is referred to the Geologic Map of Alabama, scale 1 to 500,000, published in 1926, and to the U. S. Geological Survey Geologic Atlas (Montevallo-Columbiana, Stevenson, Gadsden, Bessemer-Vandiver, and Birmingham folios).

Physical Divisions of Alabama

The surface rocks of Alabama include, in the eastern part of the state, igneous and metamorphic rocks, of pre-Cambrian and later age, a great thickness of Paleozoic sediments in the northern part of the state, ranging in age from Cambrian to Pennsylvanian, and Cretaceous, Tertiary, and Quaternary sedimentary rocks in the large Coastal Plain area in the southern part of the state.

Extensive warping and folding of the beds in certain areas accompanied and followed by a long period of erosion give the hard rocks topographic relief and make it possible for the state to be divided conveniently into physiographic provinces. These are shown in figure 1. The distribution and development of the shales of Alabama are closely related to these physiographic provinces and their strata.

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[1] References:

Johnston, W. D., Jr., Physical divisions of Northern Alabama: Alabama Geol. Survey, Bull. 38, 1930.

Adams, G. I., The crystalline rocks, in Adams, G. I., and others, Geology of Alabama: Alabama Geol. Survey, Spec. Report 14, pp. 25-40, 1926.

Adams, G. I., The crystallines of Alabama: Jour. Geology, vol. 41, no. 2, pp. 159-173, 1933.

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Butts, Charles, U. S. Geological Survey Geol. Atlas, Birmingham folio (no. 175), 1910.

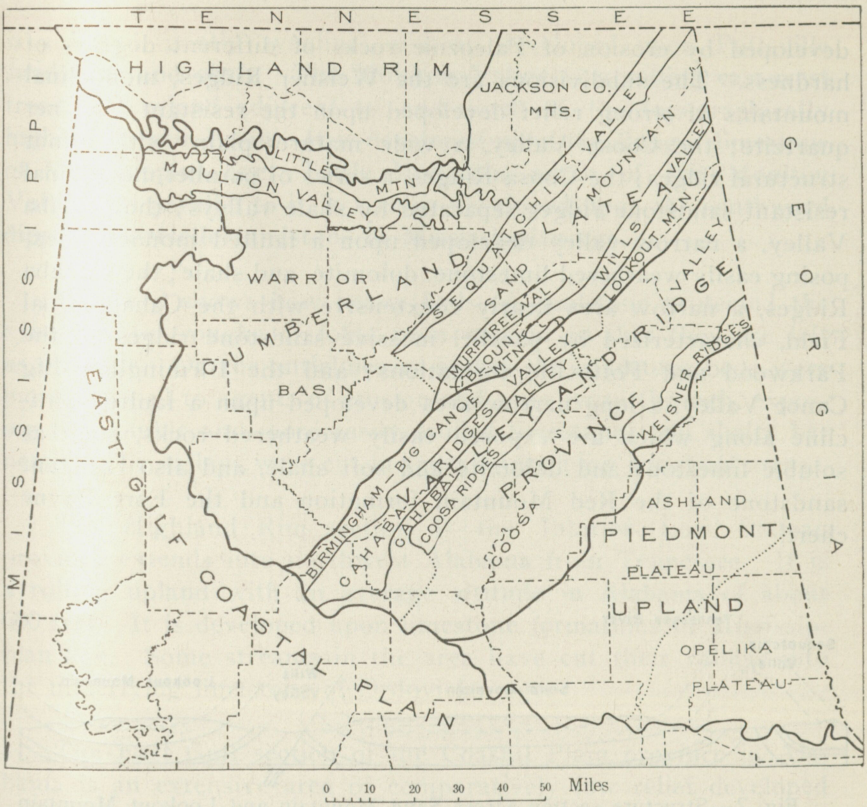
TENNESSEE
MISSISSIPPI
GEORGIA
HIGHLAND RIM
JACKSON CO. MTS.
LITTLE MTN
MOULTON VALLEY
WARRIOR BASIN
CUMBERLAND PLATEAU
SEQUATCHIE VALLEY
SAND MOUNTAIN
WILLS VALLEY
LOOKOUT MTN
MURPHREE VAL
BLOUNT MTN
VALLEY AND RIDGE PROVINCE
WEISNER RIDGES
BIRMINGHAM—BIG CANOE VALLEY
CAHABA VALLEY
CAHABA RIDGES
COOSA RIDGES
COOSA VALLEY
ASHLAND PLATEAU
PIEDMONT UPLAND
OPELIKA PLATEAU
EAST GULF COASTAL PLAIN
0 10 20 30 40 50 Miles

Fig. 1.—Physical divisions of northern Alabama.

The Piedmont Upland section of the Piedmont province is a submaturely dissected surface developed upon igneous and metamorphic rocks of pre-Cambrian to Pennsylvanian age. The subdivisions of the Piedmont Upland section are the Opelika Plateau on the east, an old peneplain developed on the ancient pre-Cambrian rocks, and the Ashland Plateau on the west, a well dissected rolling upland with mountainous ridges along the western border, developed on igneous and metamorphic rocks of Paleozoic age. The area underlain by the Talladega series is included in the Piedmont Upland section in the northern part of the area of out-crop where high ridges are developed upon the resistant beds, but south of Cleburne County it is included in the Valley and Ridge province.

The Valley and Ridge province, as its name implies, is characterized by long valleys and ridges of northeast-southwest trend developed by erosion of Paleozoic rocks of different degrees of hardness. The subdivisions are the Weisner Ridges, monoclinal mountains of strong relief developed upon the resistant Weisner quartzite; the Coosa Valley, a wide mature plain with minor structural ridges; the Coosa Ridges, a series of parallel monoclinal resistant sandstone ridges separated by shale valleys; the Cahaba Valley, a narrow valley developed upon a faulted monocline exposing easily weathered limestone, dolomite, and shale; the Cahaba Ridges, a narrow area nearly coextensive with the Cahaba Coal Field, characterized by parallel massive sandstone ridges of the Parkwood and Pottsville formations; and the Birmingham-Big Canoe Valley, a long narrow area developed upon a faulted anticline along which are exposed easily weathered rocks, such as soluble limestone and dolomite and soft shale, and also resistant sandstone of the Red Mountain formation and the Fort Payne chert.

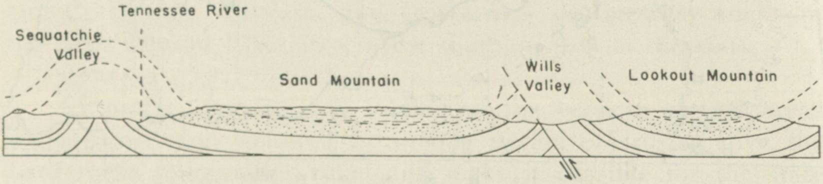

Fig. 2.—Structure section across Sand Mountain and Lookout Mountain in the vicinity of Scottsboro and Ft. Payne.

The Cumberland Plateau section of the Appalachian Plateau province is a submaturely to maturely dissected upland developed largely upon nearly flat-lying Pennsylvanian sandstone, shale, and coal beds. In the northern and eastern part of the section the resistant Pottsville sandstone of Pennsylvanian age upholds elongate synclinal mountains which are separated by anticlinal valleys formed by the erosion of soluble older Paleozoic limestone and dolomite. The subdivisions of the Cumberland Plateau section are Lookout Mountain, Wills Valley, Sand Mountain, Sequatchie Valley, Jackson County Mountains, Blount Mountain, Murphree Valley, Warrior Basin, Moulton Valley, and Little Mountain. The Jackson County Mountains district contains mesas capped by resistant Pottsville sandstone, and the remainder of the area, about two-thirds, is topographically lower with stream valleys cut into the underlying limestones of Mississippian age. The Warrior Basin is a broad, gently synclinal, plateau developed upon Pottsville sandstone and shale. The Moulton Valley is a rolling east-west trending lowland adjacent to, and north of, the topographically higher Warrior Basin. It is developed upon the Bangor limestone of Mississippian age. Little Mountain, north of the Moulton Valley and parallel to it, is a ridge developed upon the southward dipping Hartselle sandstone of Mississippian age.

Figure 2 shows how heavy beds of sandstone protected the synclines or troughs of folds from erosion so that they are left as plateaus. On the anticlines or arches the sandstone beds were more exposed to agents of erosion and were worn through, exposing the soluble and more easily eroded limestones and shales beneath. The valleys were cut in these intervening anticlinal areas.

The Highland Rim section of the Interior Low Plateau province extends into northwest Alabama from Tennessee. It is a rolling upland with an average altitude in Alabama of about 600 feet. It is developed upon limestone formations of Mississippian age. Some streams in the area have cut their valleys into the underlying limestone of Ordovician age.

The East Gulf section of the Coastal Plain province in Alabama is an extensive area of comparatively low relief developed upon unlithified sediments of Mesozoic and Cenozoic age. The beds have a gentle monoclinal dip southward in east Alabama and southwestward in west Alabama. The section has been subdivided into several belts of different relief resulting from differential erosion of harder and softer beds. Hard sandstone and claystone beds in the sequence of sedimentary rocks give rise to cuestas such as the Ripley and Tallahatta cuestas, and soluble limestone and chalk beds to lowland areas of low relief, such as the Black Belt. As the Coastal Plain contains no commercially important shale deposits, the physical subdivisions, or belts, are not named and described in this report.

Crystalline Rocks

The crystalline rocks which underlie the Piedmont Upland in Alabama occur in belts having a general northeast and southwest trend. The northwestern border of the area of outcrop in many places is marked by a bold escarpment where the crystalline rocks rise above the general surface of the unaltered Paleozoic rocks. The crystallines have been thrust to the northwest on the unaltered Paleozoics and the trace of this great overthrust fault marks the northwestern boundary. To the south the crystallines are covered by sedimentary deposits of Upper Cretaceous age.

Talladega series: This series of more or less metamorphosed sediments crops out in a northeast-southwest belt 10 to 20 miles wide along the northwestern border of the crystalline area. The total thickness of the series may be 30,000 feet. It consists largely of slate and sericitic phyllite in which are interbedded, at certain localities, conglomerate, sandstone, limestone, marble, dolomite, chert, graphitic phyllite, and quartz schist. Some of these were mapped and described as members of the Talladega slate by Butts in Special Report 15 of the Alabama Geological Survey published in 1926. Later, subdivisions of the lower part of the Talladega were given formation names by Butts in the Montevallo-Columbiana folio published in 1940. The age of the Talladega series ranges from probable pre-Cambrian to Pennsylvanian. The original rocks were largely clay shale or sandy shale, but have been metamorphosed to slate and phyllite as a result of compressive forces. Slaty cleavage, which is strongly developed, strikes northeast-southwest, dips steeply to the southeast, and obscures the original bedding.

Several distinct lithologic units in the Talladega series have been named. In the southwestern part of the area of outcrop Butts has distinguished the Waxahatchee slate which contains the Sawyer limestone member, the Brewer phyllite, and the Wash Creek slate which contains the ferruginous sandstone member and the massive sandstone member. Also included in the lower part of the Talladega series in the area of outcrop in Alabama are the Sylacauga marble, possibly equivalent to the Sawyer limestone, the Jumbo dolomite, the Butting Ram sandstone, and its possible equivalent the Cheaha sandstone. In the upper part of the Talladega are the Jemison chert and Yellow Leaf quartz schist of lower Devonian age, the Dempsey marble, and the Erin shale of Pennsylvanian age.

The Waxahatchee slate is composed mainly of grayish, greenish, and bluish slate, or phyllite, which becomes soft and light gray, yellow, or pale pink on weathering. The formation is about 5,000 feet thick and contains several thin layers of sandstone and the Sawyer limestone member.

The Brewer phyllite, a persistent stratum of purple-gray phyllite, having a finely banded fissile structure and silky sheen, overlies the Waxahatchee slate. It is lithologically similar to the main body of the great slate or phyllite mass of which it is a part, but it is distinguished by its characteristically purple color. The thickness of the formation ranges from 200 to 500 feet.

The Wash Creek slate is similar to the Waxahatchee slate in lithology and color and is distinguished mainly by its stratigraphic position above the Brewer phyllite. The lower part of the formation is a sandy phyllite or quartz schist containing the ferruginous sandstone member. The upper part is less sandy and contains a heavy bed of conglomeratic sandstone with black slate or schist beneath. The thickness of the formation is estimated to be 5,000 feet.

The upper part of the Talladega series is made up of slate, or phyllite, or schist similar to that in the lower formations of the series. The Jemison chert, Yellow Leaf quartz schist, Dempsey marble, and Erin shale occur in the upper part of the series. The Erin shale, a black carbonaceous shale or slate weathering light gray, crops out in the vicinity of Erin in Clay County. Fossils indicate a probable Pennsylvanian age. The formation has an average dip of 45 degrees east and a thickness of about 2,000 feet.

Other crystalline rocks: The Hillabee chlorite schist is an intrusive sill of altered igneous rock of probable post-Carboniferous age cropping out along the east edge of the Talladega series. The Ashland mica schists are metamorphosed sediments apparently of pre-Cambrian age. The Wedowee formation consists of phyllite, slate, and quartzite, and is characterized in many places by the occurrence of amorphous graphite. The Pinckneyville granite is an intrusive igneous mass of probable post-Carboniferous age with associated pegmatites which are the source of the mica mined in Alabama. The Dadeville, Opelika, Wacoochee, and Uchee belts of Adams (1933) comprise the area mapped as Archean on the Geologic Map of Alabama published in 1926 The area is underlain by a variety of metamorphic rocks which are cut by four known diabase dikes, possibly of Triassic age, trending northwest-southeast across the strike of the older formations.

Paleozoic Rocks

Cambrian system.—The formations that are of undoubted Cambrian age in Alabama are, in ascending order, the Weisner formation, Shady ("Aldrich", "Beaver") limestone, Rome ("Montevallo") formation, and Conasauga ("Coosa") formation.

The Weisner formation crops out from central Shelby County northeastward into southeast Cherokee County and into Georgia. The formation consists predominantly of shale and sandy shale, slightly metamorphosed in most places, with interbedded hard quartzite, conglomerate, and sandstone. The dark blue-gray shale weathers yellowish gray. In places the shale contains a considerable proportion of thin layers or bands of sericitic quartzite. The gray siliceous hematite iron ore beds of Talladega County occur in the Weisner formation. The thickness of the Weisner is uncertain but is estimated to be 1700 to 5500 feet.

The Shady limestone, 500 to 600 feet in thickness, is not well exposed in Alabama. The area of outcrop is characterized by a deep red soil several feet thick.

The Rome ("Montevallo") formation is made up of red and green shale, chocolate sandstone, fine-grained rusty-weathering calcareous sandstone, and local beds of fairly pure limestone and dolomite. The red shale and rusty-weathering calcareous sandstone are the distinguishing lithologic features. Much of the shale of the Rome formation is sandy. The thickness of the formation has not been accurately determined, but may be 1000 to 4000 feet according to estimates.

The Conasauga ("Coosa") formation is composed of limestone, dolomite, and shale which vary in relative proportions in different areas. The limestone is blue and mostly thin-bedded. The shale has a greenish-gray or yellow-green color, weathers yellow, and occurs interbedded with thin limestone layers and, in places, in thick beds. The thick beds of shale include many thin layers of limestone. The thin-bedded weak rocks of the Conasauga have been intensely crumpled in many areas as a result of thrust faulting. The thickness of the formation ranges from 500 feet to about 1900 feet.

Cambrian or Ordovician system.—The formations that are of Cambrian or Ordovician age in Alabama include, in ascending order, the Brierfield, Ketona, Bibb, Copper Ridge, and Chepultepec dolomites. This great mass of dolomite is 5,000 to 5,500 feet thick and comprises most of the Knox dolomite of early Alabama reports. The formations are not described here as no shale beds are included in the sequence.

Ordovician system.—The formations of undoubted Ordovician age in Alabama are, in ascending order, the Longview, Newala, Odenville, Mosheim, and Lenoir limestones, the Athens shale, and the Little Oak limestone. The Chickamauga limestone includes rocks of early to late Ordovician age. This predominantly limestone section of Ordovician age, with the exception of the Longview limestone, was included in the "Pelham limestone" of early Alabama reports.

The Longview is composed of cherty limestone and some dolomite and is about 500 feet thick. The Newala consists mostly of gray compact very pure limestone about 1,000 feet thick. The Odenville is an impure cherty limestone about 50 feet thick. The Mosheim is a thick-bedded compact blue-gray limestone about the same thickness, and the Lenoir is a dark finely crystalline low-magnesian limestone about 500 feet thick.

The Athens shale consists predominantly of black fissile shale with graptolite fossils. It contains a few layers of gray compact limestone. Where unweathered, the shale is highly calcareous. The thickness of the formation is very irregular and ranges from 15 to 350 feet. The Little Oak is a dark rather coarsely crystalline somewhat cherty limestone 50 to 500 feet thick.

The name Chickamauga limestone is applied to beds of Ordovician age lying northwest of the Cahaba coal field and northwest of Calhoun County. The Attalla conglomerate member occurs in places at the base of the formation. Overlying the conglomerate in places is a greenish clay shale which in turn is overlain by a variegated limestone. The remainder of the formation is composed of thick-bedded blue fine-grained limestone. The thickness of the formation differs from place to place, ranging from 200 to 500 feet.

Silurian system.—The rocks of Silurian age in Alabama are included in the Red Mountain formation. The formation contains the important seams of hematite or red iron ore known as the Irondale seam and the Big seam, which are mined in the vicinity of Bessemer and Birmingham. In this region the formation contains, in ascending order, shaly beds 100 feet thick containing one massive sandstone bed, the Irondale ore bed which is 4 to 5½ feet thick near Irondale, shale and sandstone layers of irregular thickness owing to erosion before deposition of higher beds, but ranging from 3 to 27 feet, the Big seam of red iron ore 17 feet thick, red sandstone with yellow shale in the lower portion, about 20 to 40 feet thick, the Ida seam 2 to 6 feet thick, sandstone and shale beds about 20 feet thick, a ferruginous sandstone called the Hickory Nut seam, and shale and reddish sandstone beds 70 feet thick. The total thickness of the Red Mountain formation in the Birmingham region is 180 to 270 feet. It is 600 to 700 feet thick near Fort Payne. In the northern part of Alabama, north of the Tennessee River, the equivalent beds exposed in small areas are all limestone. The Red Mountain formation expresses itself topographically in long straight ridges where it has been tilted up at steep angles by folding, owing to the resistant nature of the clastic beds and its close association with the overlying resistant Fort Payne chert.

Devonian system.—This system includes the Jemison chert and the Yellow Leaf quartz schist already described in the section on crystalline rocks, the Frog Mountain sandstone, and the Chattanooga shale, the age of which, however, is in dispute.

The Frog Mountain sandstone consists of dark sandstone and siliceous shale. Its thickness ranges from a few inches to 50 feet, but in Frog Mountain in southeastern Cherokee County it is 350 feet.

The Chattanooga shale is a nearly homogeneous mass of densely black, highly fissile or slaty shale 20 to 30 feet thick in northeastern Alabama. It thins southward, and south of Murphree Valley it is represented by 1½ to 5 feet of reddish and yellowish green clay in weathered outcrops.

Mississippian system.—The Fort Payne ("Lauderdale") chert, the Tuscumbia (Warsaw and St. Louis) and Ste. Genevieve limestones, the Bethel sandstone, the Gasper formation, the Cypress sandstone, the Golconda formation, the Hartselle sandstone, the Bangor limestone, the Pennington formation, the Floyd shale, and the Parkwood formation comprise the Mississippian system in Alabama. Limestone is the predominant type of rock in northwest Alabama, but clastic rocks, sandstone and shale, predominate southeast of Birmingham-Big Canoe Valley.

The Fort Payne chert is composed of resistant solid chert with a porous stony texture and splotched with black and rust-colored stains. In Lauderdale County the formation contains as much as 60 feet of dark shale and lenses of massive limestone in the basal portion. The Fort Payne ranges in thickness from 200 feet in Lauderdale County to 100 feet east of the Coosa River.

The Tuscumbia limestone is the mapped unit in Alabama that is equivalent to the Warsaw and St. Louis limestones of the Mississippi Valley region. The formation consists of dark thick-bedded coarsely crystalline fossiliferous limestone. The formation is about 150 feet thick at Blount Springs, but thickens to about 350 feet in the Tennessee Valley.

The Ste. Genevieve limestone is present throughout the Tennessee Valley but does not extend far south of that area. It consists of oolitic limestone except in Colbert County where a soft green shale or marl facies is present. The formation is 75 to 100 feet thick in the Tennessee Valley.

The Bethel sandstone, a thick-bedded to shaly sandstone 10 to 20 feet thick and locally asphaltic, occurs in Colbert County only.

The Gasper formation consists of oolitic pure limestone in northeast Alabama in Jackson and Madison Counties, but this changes to a shale facies to the south and west. A persistent bed of asphaltic oolitic limestone occurs at the base of the shale facies south of the Tennessee River in Colbert County. The soft marly shale, containing thin layers of limestone, weathers to a greenish clay. The thickness of the oolite facies is about 100 feet and the shale facies about 100 to 150 feet.

The thick-bedded Cypress sandstone occurs only in Colbert County where it reaches a thickness of 40 feet. The Golconda formation, a green marl with oolitic limestone below, about 40 feet thick, also is known only in Colbert County.

The Hartselle sandstone is a widely distributed formation and is expressed topographically in distinct ridges where it is tilted up at a steep angle. In Colbert County it consists of thick-bedded, medium-grained sandstone, overlain by thin-bedded sandstone with interbedded shale. In most areas of outcrop the sandstone is thick-bedded and the quartz grains are well cemented. The thickness ranges from 200 feet in southern Colbert County, to 75 feet in Jefferson County, and 5 to 10 feet in Madison County.

The Bangor limestone consists of dark-blue thick-bedded crystalline and oolitic limestone. The lower part is a marly or shaly limestone in Colbert and Franklin Counties. The thickness ranges from 700 feet in northeast Alabama to about 400 feet at Blount Springs. East of Birmingham-Big Canoe Valley the equivalent formation is the Floyd shale.

The Pennington formation is composed mainly of argillaceous (clayey) limestone beds and red and gray shale beds. The red shale is characteristic of the formation. The thickness is about 50 feet, but may be as much as 200 feet in places.

The Floyd shale, which occurs southeast of the Warrior basin and Lookout Mountain, is the clastic facies equivalent of several formations, chiefly limestone, from the base of the Ste. Genevieve to the top of the Bangor, which crop out in north Alabama. The formation consists predominantly of shale, most of it a dull-greenish color and crumpled character. It crumbles easily into small flakes with slickensided surfaces giving them a greasy appearance. The formation also contains some black fissile, slaty, shale. Interbedded with the shale are many lenses and layers of fine-grained greenish sandstone, a few layers of dark limestone, and in places a thin-bedded fossiliferous shaly limestone weathering to shale. The area underlain by the Floyd is low and poorly drained and has clayey soil. Weathering is not deep, however, and comparatively fresh bed rock is exposed in numerous road cuts and ravines. The formation is about 1,200 feet thick in Shelby County and perhaps 2,000 feet thick northeast of Shelby County.

The Parkwood formation lies above the Floyd shale in the Cahaba and Coosa coal fields and above the Bangor or Pennington formation on the south end of Blount Mountain. It is absent in other areas. It is composed of clay shale and thick beds of siliceous to feldspathic ridge-making sandstone. Both the shale and the sandstone are characteristically gray in color where fresh. The Parkwood contains fossils of Mississippian age and Pennsylvanian age and is thought to bridge the gap between the two systems which, in the remainder of the Appalachian region, are separated by a hiatus or unconformity. It resembles the overlying Pottsville formation but contains no coal. The thickness of the Parkwood ranges from 1,000 feet on the east end of the Coosa coal field to 2,000 feet in Shades Mountain near Birmingham, and to 400 feet on the east slope of Blount Mountain.

Pennsylvanian system.—The rocks of Pennsylvanian age in Alabama are included in the Pottsville formation, described below, and in the Erin shale, which has already been described in the section on crystalline rocks.

The Pottsville is a thick mass of successive sandstone, shale, and coal beds. Owing to resistant beds in the sequence, the areas underlain by the Pottville are plateaus bounded by steep escarpments. The Pottsville formation at one time was continuous over all of north Alabama, but after folding and faulting and erosion of the uplifted anticlinal areas, the Pottsville beds were left in several separated areas. These are now know as the Warrior, Cahaba, Coosa and Plateau coal fields. The Plateau field in the northeast part of the state is made up of a number of separated areas, including Sand Mountain and Lookout Mountain.

The base of the Pottsville is placed at the base of the Brock coal seam which underlies the Shades sandstone (basal sandstone of the "Millstone grit") in the Cahaba field. In the lower part of the Pottsville, exposed along the northwest margins of the Cahaba and Coosa fields, occur three thick beds of rather pure siliceous sandstone, locally conglomeratic. These beds, frequently called "Millstone grit", make prominent ridges and are separated by shale beds that carry thin coal beds in places. Sandstone beds higher in the sequence are commonly thick-bedded and more or less feldspathic. In the Warrior field the thick basal sandstone is called the Boyles sandstone member. The upper part of the Pottsville, in the southern part of the Cahaba field, above the Thompson coal bed consists in large part of coarse conglomerate with boulders up to 6 inches in diameter.

Some of the shale beds of the Pottsville formation are more or less sandy, but others are nearly pure clay shale. Most of the clay shale is dark from carbonaceous matter. Shale beds make up about two-thirds of the Pottsville formation and are the source of most of the shale used in the ceramic industry in this state.

Coal beds are distributed throughout the Pottsville formation in all of the fields, but not all are of minable thickness or quality. The workable beds in the Warrior coal field total 11, in the Cahaba field about 15, in the Coosa field about 12, and in the Plateau field one bed is of workable thickness. The lower part of the Pottsville, within the sequence of beds known as the "Millstone grit", includes no commercially workable coal beds in the Coosa field. In the Warrior field no workable beds occur below the Black Creek bed, and in the Cahaba field below the Gould bed.

The Pottsville formation is 9,000 feet thick in the southern part of the Cahaba field. It thins to 2,800 feet in the Coosa field, 2,300 feet in the Warrior field, and about 1,000 feet in the Plateau field.

Upper Cretaceous and Tertiary Rocks

Rocks of Upper Cretaceous, Tertiary, and Quaternary ages underlie the Coastal Plain of Alabama. Nearly all of the beds are soft and unlithified, but a few hard beds of limestone, sandstone, and claystone occur in the sequence. None of the formations contains beds of true or typical shale similar to the typical shale beds of the Pottsville and other Paleozoic formations. The Coastal Plain beds which resemble the Paleozoic shale beds are actually composed of alternating thin laminae of clay and sand or silt. The shaly character is not a result of compaction of the bed as in the Paleozoic shales, but of rapid alternations in conditions during deposition, so that thin layers of clay and silt are deposited in succession. Beds of this character are common throughout the Upper Cretaceous and Tertiary sequence, but are especially characteristic of the formations of the Midway and Wilcox groups of the lower Tertiary. These beds are thought to have been deposited in extensive coastal swamps and estuaries. Several beds of lignite or brown coal are present in these formations.

Cretaceous and Tertiary beds resembling shale in character would not be suitable for the manufacture of clay products owing to their high sand or silt content. The Coastal Plain beds, however, contain several commercially important beds of clay and kaolin, but these are described in other publications and a discussion of them is outside the scope of this report. The Upper Cretaceous and Tertiary formations therefore are treated in a cursory fashion in the following paragraphs.

Upper Cretaceous series.—The formations of this series include the Tuscaloosa formation with sand, gravel, and shale-like beds and commercially important clay deposits; the Eutaw formation with cross-bedded sand and shale-like sand and clay beds; the Selma chalk; the Blufftown formation; the Cusseta sand; the Ripley formation with sand and clay and hard calcareous beds; the Prairie Bluff chalk; and the Providence sand.

Paleocene series.—The formations of this series in Alabama are the Clayton formation, which is mainly limestone and calcareous sandstone; the Porters Creek (Sucarnoochee) clay, which is a uniform massive black clay; the Naheola formation, which contains about 100 feet of shale-like, laminated sand and clay layers with lignite beds, and a greensand bed at the bottom and at the top.

Eocene series.—This series contains the Nanafalia formation, which consists of sand, fossiliferous marl, and claystone; the Tuscahoma, Bashi, and Hatchetigbee formations, which are predominantly composed of shale-like beds, made up of sand and clay laminae, with several fossiliferous marl beds and lignite beds; the Tallahatta formation, which is largely claystone; the Lisbon, which consists of calcareous and glauconitic sandy clay and sand; the Gosport sand; the Moodys marl; the Yazoo clay; and the Ocala limestone.

Oligocene, Miocene, and Pliocene series.—The formations included in these three series are the Red Bluff clay, the Marianna limestone, the Glendon limestone, the Bucatunna clay, the Chicasawhay marl, the Paynes Hammock sand, the Catahoula sandstone, the Hattiesburg clay, the Pascagoula clay, and the Citronelle formation.

Formations Having Shales of Possible Economic Value

Results of tests made in the course of this investigation indicate that clay shales of the Parkwood and Pottsville formations are the most satisfactory for the manufacture of ceramic products. Some of the weathered clay of the Conasauga formation also could be used in the ceramic industry. In places where the shale is weathered and not too calcareous it might be used, but the fresh shale that was tested was unsatisfactory. Much of the Floyd shale is not plastic and the working properties are unsatisfactory, but the soft shale beds in some areas could be used. Samples from shale beds in the Gasper formation had good working properties, but the results of the firing tests were not very satisfactory. Samples from the Waxahatchee slate and other formations included in the Talladega series did not slake well and lacked plasticity owing probably to metamorphism of the beds. One sample of weathered clay from an outcrop of the Talladega series proved quite satisfactory for use in making ceramic products, and samples from several outcrops of the Waxahatchee slate indicate that beds in that formation in some areas could be utilized for making common brick. Shale in the Weisner formation does not have good working properties, as it does not slake well and lacks plasticity owing to slight metamorphism and, in places, to its sandy character. Some shale beds of the Weisner formation, however, could be used in making common brick. Some shale beds included in the Red Mountain formation have good working properties and could be used in the ceramic industry. The samples tested, however, have a short vitrification range. Samples from the Rome formation proved to be rather unsatisfactory. The material was difficult to work, did not slake well, was too sandy, and lacked plasticity. The Coastal Plain shale-like beds, or bedded sandy clays, are rather unsatisfactory as they are too sandy, but some of the less sandy beds could be used for bond clay. A bed of carbonaceous clay in the Tuscaloosa formation in northwest Alabama has unusual properties and could be used in processing refractories.

Owing to the thinness of the formations, or some other feature that makes them unfit for commercial exploitation, some shale formations described in the section on Paleozoic rocks were not sampled and tested. The Chattanooga shale, for example, is less than

20 feet thick in Alabama except in the northeastern part of the state where it reaches a maximum thickness of 30 feet. The Pennington formation likewise is very thin in Alabama and is overlain by thick sandstone beds making strip mining impossible. The Athens shale is very irregular in thickness, ranging from 15 to 350 feet. The fresh shale has a high calcium carbonate content which is an objectionable feature.

Shale beds of the Pottsville formation have been quarried at a number of places for use in the ceramic industry. Similar shale from the Parkwood formation has also been used at some places. Most of the shale of the Pottsville is probably suitable for making brick or other ceramic products. Several shale beds at different places in the stratigraphic sequence have been utilized in the Warrior basin. A blue clay shale bed about 200 feet thick occurring above the Mary Lee coal group is probably the highest bed used. It is a very persistent bed and extends throughout the basin where not removed by erosion. It contains a few sandstone layers. Although uniform in appearance, it may show variations in composition and properties at different places. Several other shale beds lower in the stratigraphic section have been used at other places in the Warrior basin. At Lovick, in the Cahaba coal field, a shale bed between the Gould and Nunnally coal groups has been utilized for making brick. The section in the quarry shows at the bottom 20 feet of blue-black carbonaceous clay shale with fossils, 18 feet of gray clay shale, and at the top, 10 feet of reddish or yellowish shale which is probably the weathered part of the gray shale. Shale from all three layers is mixed for making brick. At most plants a certain proportion of weathered shale is mixed with the fresh shale, but at some plants Pottsville shale is mixed with fire clay from the Warrior field for making sewer pipe.

Shales of the Pottsville formation are well suited for the manufacture of ceramic products. The quantity of good shale is unlimited, conditions for quarrying are excellent at many places, fuel is plentiful, and transportation facilities are favorable.

THE FIRE CLAYS OF THE POTTSVILLE FORMATION

A fire clay known as the Black Creek underlies the Black Creek coal seam of the Pottsville formation in the Warrior Coal Field of Alabama, and is the only coal-measure fire clay mined in the state.

It is dark gray in color due to carbonaceous matter, breaks with a conchoidal or hackley fracture, and shows the characteristic "slickensides" of many under clays. It contains some iron sulfide which on firing causes dark or slagged spots. The clay varies in its physical properties over quite small areas as in some mines it is sandy and in others it is smooth and fine-grained. There are also differences in firing, shrinkage, porosity, and fusion points (see table 3).

From the refractory standpoint the Black Creek clay would be classed as a semi to low refractory clay.[1]

It has been used extensively for making ladle brick for steel plants, and these brick are considered to be the best in the United States for this purpose. Also, it is used in small amounts as a bond clay in high-grade refractories and has been utilized at Cordova for making buff, gray and glazed brick and tile.

Next to the shales, the Black Creek clay may be considered the most important ceramic material of this type found in Alabama.

TESTING OF SHALES AND FIRE CLAYS

Preparation of samples

The samples as received from the field weighed from 50 to 100 pounds. These were dried and representative samples weighing about 25 pounds were prepared for testing. The shale or fire clay was crushed in a jaw crusher, screened and the oversize passed through a disk pulverizer until the entire sample was reduced to the proper grain size. Samples 1-10 were screened to minus 10 mesh, which is about the size used in the industry. However, some of the clays were too coarse to be readily formed into bars by the small auger machine, and all subsequent samples were screened to pass 20 mesh.

The crushed samples were mixed with water to the proper working consistency as judged by the feel. The plastic clay was then wedged into blocks and the blocks stored in a damp jar for 24 hours.

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[1] Ries, H., Clays, Occurrence, Properties and Uses, Page 335, John Wiley & Sons, Inc., 1927.

Forming test bars

All bars were extruded by means of a deairing auger machine made by the International Clay Machinery Company (figure 3). This is equipped with a 1 1/16 inch square die with the corners slightly rounded. The die is not lubricated. The pug mill operated under 25 inches of vacuum.

The clay column was extruded in a mitered trough, and 30 bars three inches in length were cut for drying and firing tests. Fifteen bars six inches in length were reserved for transverse strength tests.

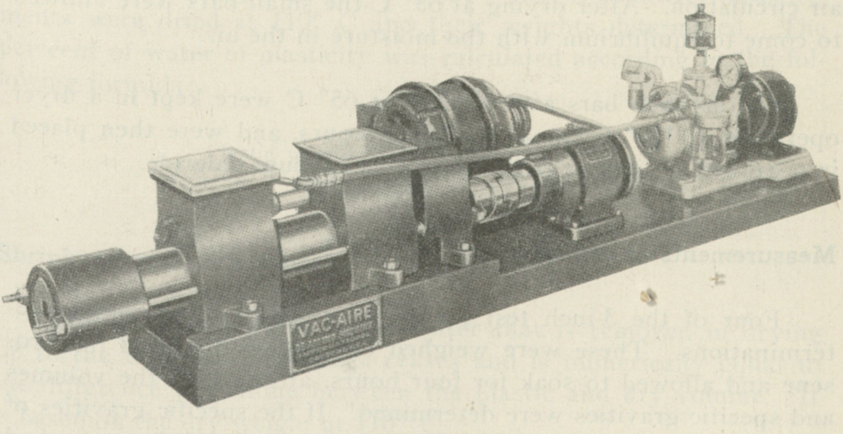

Fig. 3.—Laboratory de-airing extrusion machine. (Courtesy International Clay Machinery Company.)

Measurements of plastic bars

Eight small bars were weighed as soon as formed and three of these were used for determining the water of plasticity. The five remaining were weighed suspended in kerosene and their volumes determined according to the usual formula:

$$\text{Plastic volume} = \frac{\text{Weight of plastic bar} - \text{weight suspended in kerosene}}{\text{Density of kerosene}}$$

The specific gravities of the five bars were determined according to the following formula:

$$\frac{\text{Weight}}{\text{Volume}}$$

The specific gravity serves as a check on the mixing and forming, for if the clay does not have a uniform water content, any variations are reflected in the specific gravity data.

Drying procedure

All bars were covered with cloths and allowed to dry for one day. They were then air-dried until shrinkage ceased. The bars were subsequently dried at 65° C in an electric dryer with forced air circulation. After drying at 65° C the small bars were allowed to come to equilibrium with the moisture in the air.

The six-inch bars after drying at 65° C were kept in a dryer operating at 110° C for at least four hours, and were then placed in a cabinet desiccator over anhydrous calcium chloride.

Measurements of dry bars

Four of the 3-inch test pieces were selected for volume determinations. These were weighed dry and then placed in kerosene and allowed to soak for four hours, after which the volumes and specific gravities were determined. If the specific gravities of the four test pieces checked within .02 or if three of them checked within .01, the average of the specific gravities of either the four or three pieces was used for calculating the volumes of the remaining 26 test bars. If the specific gravities did not check within the above limits, all of the volumes were determined by the suspended weight method.

This method of determining volumes saves a large amount of time, and is reasonably precise, however, it is necessary that all test pieces have the same moisture content or large errors will result.

Drying shrinkage

The percent volume drying shrinkage was calculated according to the usual formula:

$$\frac{\text{Plastic volume} - \text{dry volume}}{\text{Dry volume}} \times 100$$

The percent linear drying shrinkage was calculated using the relation:

$$\left(1 - \sqrt[3]{1 - \frac{B}{100}}\right) 100 \text{ where B is the volume drying shrinkage}$$

Water of plasticity

The three test pieces reserved for water of plasticity measurements were dried at 110° C and their weights determined. The per cent of water of plasticity was calculated according to the following formula:

$$\frac{\text{Plastic weight} - \text{Dry weight}}{\text{Dry weight}} \times 100$$

Shrinkage and pore water

The shrinkage water is the water that is removed in drying up to the time that shrinkage ceases and is numerically equal to the difference in volume between the plastic and dry volume. It is based on the dry weight at 110° C.

$$\text{Per cent Shrinkage water} = \frac{\text{Plastic volume} - \text{dry volume}}{\text{Dry weight}} \times 100$$

The pore water is equal to the water of plasticity — the shrinkage water.

A small shrinkage water content indicates small shrinkage. Very plastic clays will have both a high shrinkage and pore water values, whereas lean clays with low plasticity have a low shrinkage, but relatively high pore water content.

Transverse strength

The transverse strengths were measured on most of the clays that could be extruded. A few of the clays had such low dry strengths that the transverse strength could not be accurately determined. The tests were made with a Tinius Olsen briquette testing machine with special tools for applying the load at the center of the dry bar. A span of 5 inches was used and the load was applied at a rate of 100 pounds per minute. Standard sand (— 20 plus 30 mesh) was substituted for the lead shot ordinarily used in the machine.

The transverse strength was calculated according to the usual formula.

$$\text{Transverse strength lbs. per sq. in.} = \frac{3\,PL}{2\,bd^2}$$

Where L is the distance between supports in inches, P the load in pounds, b the breadth in inches and d the depth in inches.

Except for a very few clays, the results of the tests were remarkably uniform and lay within 15 percent deviation from the average value.

Firing tests

The small test pieces were oxidized at low red heat in an electric muffle furnace for at least 36 hours. This was done so that the firing to higher temperatures could be carried forward at a fairly rapid rate, otherwise it would have been necessary to hold the kiln for oxidation. Separate firings were made at cones 08, 06, 04, 02, 1, 3, 5, 7, 9, 11, and 13. Two test pieces of each clay were fired at each cone temperature. The American Ceramic Society specifications call for three pieces. However, there were 75 clays to be fired and the silicon carbide muffle would hold only 150 pieces. If three pieces of each clay had been fired at each cone temperature it would have been necessary to double the number of firings. The test bars were placed in the muffle and the muffle inserted in the gas-fired kiln. The temperature was raised to 1500° F in 5 hours and at a rate of 40° F per hour above this temperature until the desired cone deformed. The kiln was then shut off and allowed to cool to room temperature.

Measurements of fired bars

The bars were placed in a can under a bell jar and evacuated by the use of a vacuum pump. Water was then admitted to cover the bars and evacuation continued until no bubbles arose to the surface. The volumes were determined by the suspended weight method. The percent porosity was calculated by the usual formula:

$$\frac{\text{Saturated weight} - \text{dry weight}}{\text{Volume}} \times 100$$

The percentage volume shrinkage was based on the dry unfired volume and the percent linear shrinkage calculated from the volume shrinkage determinations.

Pyrometric cone equivalent

The pyrometric cone equivalent (P.C.E.) commonly known as the fusion test, was determined for all of the clays. The cones were thoroughly calcined at red heat in a small electric muffle furnace before being placed in the cone pat. This procedure decreases the tendency of the clays to bloat as the volatiles are slowly removed. The fusion tests were made in a standard A.S.T.M. gas-fired P.C.E. furnace. No difficulties were encountered with those clays having a pyrometric cone equivalent of above cone 15. Some of the clays with P.C.E.'s below cone 15 bloated and the values are inaccurate. Also, the P.C.E. of clays having a high iron content are markedly affected by the reducing or oxidizing character of the furnace atmosphere because iron oxide in a reducing atmosphere is an active flux. Insofar as possible, the tests were made in an oxidizing atmosphere.

It is not common practice to run fusion tests on shales, however, the sewer pipe manufacturers are interested in the fusion point of the clay. Also, it was thought that the fusion tests might reveal some low fusion point shales which would be satisfactory as glazes with minor additions of fluxes.

CRITERIA FOR SELECTING SHALES FOR INDUSTRIAL USE

The slaking test gives some indication of the behavior of a clay. If it slakes readily in water and if the slaked material is not excessively sandy, then there is a good probability that the material can be extruded.

The linear shrinkage is of value in determining the size of dies and also clays with high shrinkages are likely to be difficult to dry without warping or cracking. The transverse strength test is of value, in that clays with a strength of above 150 pounds per square inch can be handled safely in a dry condition. In one case, however, the dry strength is very low, but the shale has been used for making brick. Clays with high transverse strengths are of value for their bonding properties. Some of these are of the fire clay type. The manufacturer prefers a clay with a comparatively low shrinkage, both in firing and drying, to one with high shrinkage because it is easier to control the size of the product. In firing, the porosity is important. If a non-porous product is desired, then a porosity of less than 1 percent is indicated. Also, the porosity and volume shrinkage determinations establish the vitrification or safe firing range. A constant apparent porosity with constant volume shrinkage over a range of three to four cones indicates that the clay can be fired satisfactorily in a round down-draft kiln in which there is variation in the temperature between the top and the bottom. The volume firing shrinkage is a better criterion of the actual firing range than the apparent porosity, because if the clay tends to overfire or bloat, the volume will increase whereas the apparent porosity may remain constant. There are more pores developed when expansion takes place, but many of these are closed pores and consequently are not indicated by the apparent porosity values, in which only the open pores are taken into account. The determination of the total porosity involving both the open and closed pores is a tedious process as it is necessary to determine the true specific gravity of the fired clay. A clay which has low porosity at a given cone temperature and then a rapid increase in the porosity or a rapid drop in the volume shrinkage is likely to be difficult to fire in commercial operation.

Cones were used for determining the final firing conditions as they measure heat effect rather than temperature. However, for convenience a table of cones and their deformation temperatures are shown in table 1.

The firing temperatures in the laboratory may be from 100° F to 150° F higher than those used in commercial practice to obtain the same shrinkage and porosity. This is because commercial kilns are usually fired from 5 to 7 days, whereas laboratory kilns are fired for a much shorter period.

Table 1. Temperature Equivalents of Cones[1]

The Low Temperature Series

Cone No.	When fired slowly 20° C per hour °F.	When fired rapidly 150° C per hour °F.
08	1733	1742
07	1787	1814
06	1841	1859
05	1886	1904
04	1922	1940
03	1976	2039
02	2003	2057
01	2030	2093

The Intermediate Temperature Series

Cone No.	When fired slowly 20° C per hour °F.	When fired rapidly 150° C per hour °F.
1	2057	2120
2	2075	2129
3	2093	2138
4	2129	2174
5	2156	2201
6	2174	2246
7	2210	2282
8	2237	2300
9	2282	2345
10	2300	2381
11	2345	2417
12	2390	2435
13	2462	2462
14	2534	2552
15	2570	2615
16	2642	2669
17	2669	2687
18	2705	2714
19	2759	2768
20	2768	2786

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[1] Standard Pyrometric Cones. Published by the Edward Orton Jr. Ceramic Foundation, Columbus, Ohio.

The High Temperature Series

Cone No.	When heated at 100° C per hour °F
23	2876
26	2903
27	2921
28	2939
29	2984
30	3002
31	3056
32	3092
32½	3137
33	3173
34	3200

COMPARISON OF SHALES AND FIRE CLAYS USED IN ALABAMA

Shales

Table 2 gives a comparison of the physical properties of shales used for the manufacture of structural clay products in the state. It may be noted that there are very wide variations in the physical properties. For example, the linear drying shrinkage varies from 2.8 to 18.6 percent, the dry transverse strength from practically zero to 630 pounds per square inch, and there are likewise variations in the porosity and firing shrinkages of the shales fired at the same cone temperature.

If the results of the tests of all of the shales included in the report be compared with the data tabulated in table 2 it is quite evident that a very large number of shales tested can be used for the manufacture of ceramic products. However, it must be emphasized that products made from the different materials would not be of equal quality.

Fire clays

While the samples of "Coal Measures" fire clays tested are more limited in number than the shales, they also show wide variations (table 3). However, they are all characterized by high dry strength, thus they are useful as a bond. The pyrometric cone equivalent varies from cone 20 to cone 28 and tests made at frequent intervals over a period of years indicate that cone 28 is about the maximum pyrometric cone equivalent for clays of this type found in Alabama. There is also a considerable variation in the physical properties of samples taken at comparatively small distances apart and under the same coal seam.

Table 2. Comparison of Shales Used in Alabama

	Sample number				
	1	6	7	8	10
% linear drying shrinkage	4.7	3.6	3.9	2.8	3.0
% water of plasticity	23.0	23.0	17.1	21.1	20.6
Transverse strength lbs/ sq. in.	339	305	630	292	306
% linear shrinkage, cone 02	8.3	10.5	6.4	8.7	10.4
% linear shrinkage, cone 3	9.7	10.7	7.6	10.5	11.2
% linear shrinkage, cone 5	9.6	10.6	7.6	10.6	11.2
% linear shrinkage, cone 7	9.6		7.1	8.7	9.4
% apparent porosity, cone 02	11.3	2.3	13.05	13.1	7.3
% apparent porosity, cone 3	2.2	0.3	2.4	0.2	0.3
% apparent porosity, cone 5	2.4	0.15	1.15	0.3	0.3
% apparent porosity, cone 7	1.6	----	0.25	0.6	0.0
Start of overfiring, cone	9	7	9	7	7
P.C.E. Cone	14	13	13	12-13	12-13

Sample No.	Company	Location
1	Stephenson Brick Company	Lovick
6	Birmingham Clay Products Company	Birmingham
7	National Fire Proofing Company	Birmingham
8	Watkins Brick Company	Ensley
10	W. S. Dickey Clay Manufacturing Company	Birmingham

	Sample number				
	42	43	57	68	66
% linear drying shrinkage	18.6	14.1	3.1	3.4	10.8
% water of plasticity	46.0	44.3	19.0	25.7	29.2
Transverse strength lbs/ sq. in.	343	442	269	----	604
% linear shrinkage, cone 02	15.0	14.9	7.4	8.0	5.0
% linear shrinkage, cone 3	12.1	12.7	9.0	10.5	7.2
% linear shrinkage, cone 5	----	----	8.7	9.6	7.4
% linear shrinkage, cone 7	----	----	8.8		7.7
% apparent porosity, cone 02	0.7	4.9	14.0	15.9	21.1
% apparent porosity, cone 3	0.5	0.0	7.0	7.2	14.3
% apparent porosity, cone 5	----	----	4.8	6.1	13.1
% apparent porosity, cone 7	----	----	3.1	----	11.2
Start of overfiring, cone	3	3	9	5	11
P.C.E. cone	15-16	14	14	5	14

Comparison of Shales Used in Alabama—Con'd.

Sample No.	Company	Location
42	Montevallo Brick Company	Montevallo
43	Montevallo Brick Company	Montevallo
57	Alphons-Custodis Company	Ragland
68	Piedmont Brick Company	Piedmont
66	Agricola Brick Company	Gadsden

Table 3. Comparison of "Coal Measures" Fire Clays Used in Alabama

	Sample Numbers				
	3	4	5	9	11
% linear drying shrinkage	3.7	5.1	3.5	6.9	3.8
% water of plasticity	15.3	16.9	14.5	24.4	18.1
Transverse strength, lbs/ sq. in.	462	500	403	316	529
% linear firing shrinkage, cone 1	4.8	5.2	3.3	7.0	4.0
% linear firing shrinkage, cone 3	5.5	5.8	3.8	7.8	4.3
% linear firing shrinkage, cone 5	5.6	5.9	4.1	7.9	4.9
% linear firing shrinkage, cone 7	5.8	6.2	4.1	8.2	5.4
% linear firing shrinkage, cone 9	5.5	6.6	3.9	8.4	5.4
% linear firing shrinkage, cone 11	3.4	6.2	2.2	5.6	6.0
% linear firing shrinkage, cone 13	3.0	4.9	----	2.7	3.2
% apparent porosity, cone 1	14.3	16.4	18.2	17.6	21.2
% apparent porosity, cone 3	9.3	13.4	15.8	10.7	20.4
% apparent porosity, cone 5	2.0	12.6	14.0	4.2	19.2
% apparent porosity, cone 7	4.8	9.6	13.3	2.6	16.4
% apparent porosity, cone 9	3.7	7.3	11.6	2.1	13.6
% apparent porosity, cone 11	4.9	7.8	14.0	5.7	10.1
% apparent porosity, cone 13	8.9	7.1	----	13.0	15.8
P.C.E. Cone	27	28	23	20	20

Sample No.	Source	Used by.
3	Black Creek Coal Co., Thermal	Harbison-Walker Refractories
4	Clay from Cordova	Alabama Clay Products Co.
5	Dixie No. 2 mine, Kimberly	Dixie Fire Brick Company
9	Lehigh Coal Co., Lehigh	W. S. Dickey Clay Mfg. Co.
11	Stephenson Brick Co., Cordova	

DESCRIPTION OF SAMPLES AND RESULTS OF TESTS

BIBB COUNTY

Sample 41. Shale

This is a carbonaceous black shale from the Blocton Coal Mine, Black Diamond Mining Company, No. 9 mine. It is probably from above the Woodstock coal seam. The sample was obtained from a dump one mile east of Blocton, a quarter of a mile east of the railroad, and a quarter of a mile west of the No. 9 mine. Did not slake in water.

Geological formation: Pottsville

Working Properties: It was not plastic enough to be molded.

P.C.E.: Cone 13.

The shale contains considerable calcium and magnesium compounds. It might be desirable for making a light-weight concrete aggregate. There would be no mining costs as it is waste material.

Sample 100. Bedded Clay

The sample was secured from a road cut 2.3 miles south of Eoline on the University Highway, State Highway No. 6. The clay occurs in a lenticular formation with 20 x 200 feet exposed. It is a sandy micaceous clay which falls apart in water.

Geological formation: Tuscaloosa

Working properties: It is not plastic enough to be formed into test pieces.

Sample 101. Bedded Clay

The sample was taken from a road cut 6 miles north of Eoline on the University Highway, State Highway No. 6. The clay is very similar to sample No. 100 with the same general properties.

Geological formation: Tuscaloosa.

BLOUNT COUNTY

Sample 9. Fire Clay

The sample was secured at the plant of the W. S. Dickey Clay Manufacturing Company at Birmingham, and is an underclay from a coal mine at Lehigh, Alabama. It is light gray in color and slakes to a mud when placed in water.

Geological formation: Pottsville

Working properties: It worked very well even when ground to pass only 10 mesh.

Drying behavior:

Linear drying shrinkage	6.9%
Volume drying shrinkage	19.1
Pore water	14.4
Shrinkage water	10.
Water of plasticity	24.4
Drying defects	None noted.

Transverse strength: 316 pounds per square inch

Firing behavior:

Cone	Porosity	Volume Shrinkage	Linear Shrinkage	Color
	%	%	%	
08	31.4	5.2	1.8	Light cream through tans to light gray at cone 9.
06	29.35	9.0	3.1	
04	25.7	12.8	4.5	
02	20.75	17.0	6.0	
1	17.6	19.5	7.0	
3	10.7	21.7	7.8	
5	4.2	21.9	7.9	
7	2.6	22.6	8.2	
9	2.15	23.2	8.4	
11	5.7	16.0	5.6	Dark gray
13	13.0	7.8	2.7	Yellowish gray

P.C.E.: Cone 20.

The clay has a low P.C.E. value, consequently, it is not satisfactory for the manufacture of refractories. At present it is mixed with shale for the manufacture of sewer pipe, and it is valuable for this purpose as it raises the refractoriness of the shale. Also, its slaking characteristics are good and it is also plastic. Its use might be extended to other structural clay products.

CALHOUN COUNTY

Sample 67. Shale

This is a black crinkled and crumpled shale containing small partings of calcite, and is located on the Gadsden-Piedmont Highway (State Highway No. 74), 2.6 miles east of the Etowah County line in Calhoun County, and 5.8 miles west of Piedmont. The exposure is 20 feet high. The dip is about 20° east. The shale is very calcareous and does not slake.

Geological formation: Conasauga.

Working properties: Unsatisfactory as it is not plastic.

P.C.E.: Cone 7, or slightly below.

This shale is of no value for the manufacture of ceramic products.

Sample 68. Shale

The sample was taken from the pit of the Piedmont Brick Company which is near the factory. The plant is 6.1 miles southwest of Piedmont on the Anniston Highway. It is a weathered shale which slakes as plates.

Geological formation: Rome ("Montevallo").

Working properties: Does not extrude very well as it lacks plasticity. However, it can be worked.

Drying behavior:

Linear drying shrinkage	3.4%
Volume drying shrinkage	9.8
Pore water	20.2
Shrinkage water	5.5
Water of plasticity	25.7
Drying defects	None noted

Transverse strength: Weak

Firing behavior:

Cone	Porosity	Volume Shrinkage	Linear Shrinkage	Color
	%	%	%	
08	33.1	4.1	1.4	Buff
06	26.55	11.7	4.1	Salmon
04	22.7	16.2	5.7	Salmon
02	15.9	22.15	8.0	Brownish red
1	11.2	25.9	9.5	Brownish red
3	7.25	28.3	10.5	Medium brownish red
5	6.1	26.2	9.6	Medium brownish red

P.C.E.: Below cone 6, probably cone 5.

The shale has a low fusion point and does not have a long firing range. Its working properties could be improved by the addition of some plastic clay. The colors of the fired pieces are fair.

Sample 69. Shale

The sample was selected from a road cut south of Jacksonville on the Anniston Highway (State Highway No. 11), 9 miles north of Anniston. It is a very sandy soft shale with a reddish purple color. It does not slake.

Geological formation: Rome ("Montevallo")

Working properties: Poor as it was very sandy.

Drying behavior:

Linear drying shrinkage	2.7%
Volume drying shrinkage	7.8
Pore water	16.9
Shrinkage water	4.3
Water of plasticity	21.2
Drying defects	None noted

Transverse strength: Weak

Firing behavior:

Cone	Porosity	Volume Shrinkage	Linear Shrinkage	Color
	%	%	%	
08	29.9	4.0	1.4	Salmon
06	27.6	6.9	2.4	Salmon
04	26.0	8.0	2.7	Light brownish red
02	20.4	13.85	4.8	Light brownish red
1	15.65	18.5	6.6	Medium brownish red
3	9.25	22.5	8.1	Deep brownish red
5	5.8	25.3	9.3	Deep brownish red
7	1.4	23.6	8.6	Dark brownish red

P.C.E.: Cone 10.

The shale bloated at cone 7. It would probably be of little value in the manufacture of ceramic products. The colors of the fired pieces are good.

Sample 70. Shale

This is a reddish purple shale similar in appearance to sample No. 69. The deposit is on U. S. Highway No. 78 in a 10-foot exposure, 7.4 miles west of Anniston. It is very sandy but will slake.

Geological formation: Rome ("Montevallo")

Working properties: Very sandy and did not work well.

Drying behavior:

Linear drying shrinkage	3.4%
Volume drying shrinkage	9.9
Pore water	19.3
Shrinkage water	5.5
Water of plasticity	24.8

Transverse strength: Very weak. The strength is less than 150 pounds per square inch.

Firing behavior:

Cone	Porosity	Volume Shrinkage	Linear Shrinkage	Color
	%	%	%	
08	35.1	0.8	0.3	Buff
06	33.0	4.3	1.5	Salmon
04	31.3	6.9	2.4	Salmon
02	28.5	10.1	3.5	Light brownish red
1	26.5	12.3	4.3	Medium brownish red
3	24.05	15.4	5.544	Medium brownish red
5	21.6	17.3	6.1	Medium brownish red
7	13.2	24.4	9.0	Dark brownish red
9	17.00	20.0	7.2	Yellowish brown

P.C.E.: Cone 14.

This is an open firing shale and would not be satisfactory if a low porosity product were desired. It is rather difficult to work. however, it could be used for common brick. The colors of the fired pieces are fair.

CHEROKEE COUNTY

Sample 82. Shale

The sample was obtained 3.7 miles northwest of the Alabama-Georgia line on State Highway No. 74. The shale dips almost vertically and there is an exposure of 150 feet. It is a metamorphosed shale, gray in color that slakes into coarse hard fragments.

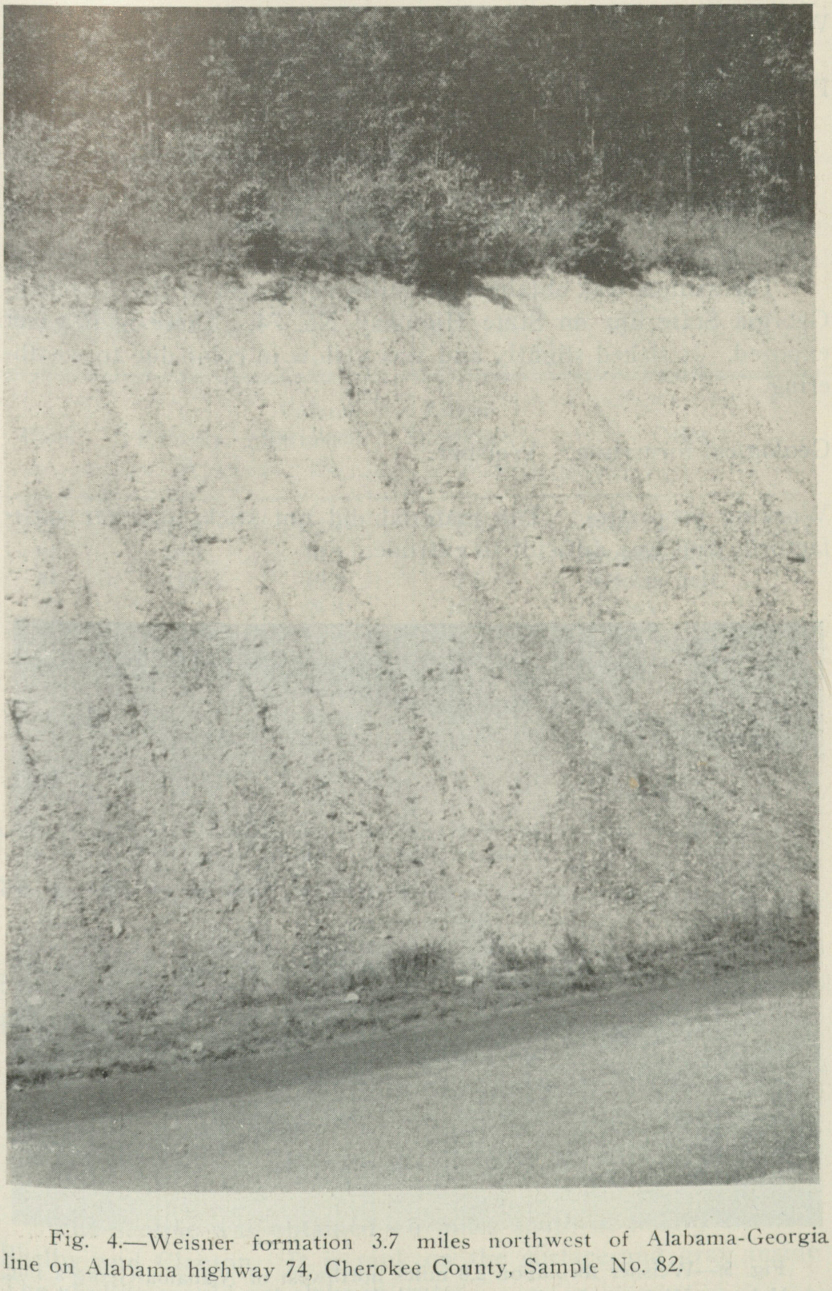


Fig. 4.—Weisner formation 3.7 miles northwest of Alabama-Georgia line on Alabama highway 74, Cherokee County, Sample No. 82.

Geological formation: Weisner.

Working properties: The shale was non-plastic.

P.C.E.: Cone 18-19.

This material appears to be of no value for ceramic purposes.

Sample 83. Weathered Schist

The sample was obtained 2.8 miles northwest of the Alabama-Georgia State line on State Highway No. 74. There is 100 feet exposed. It slaked slightly and was yellow in color due to weathering.

Geological formation: Weisner.

Working properties: The material did not stick together satisfactorily and was difficult to extrude.

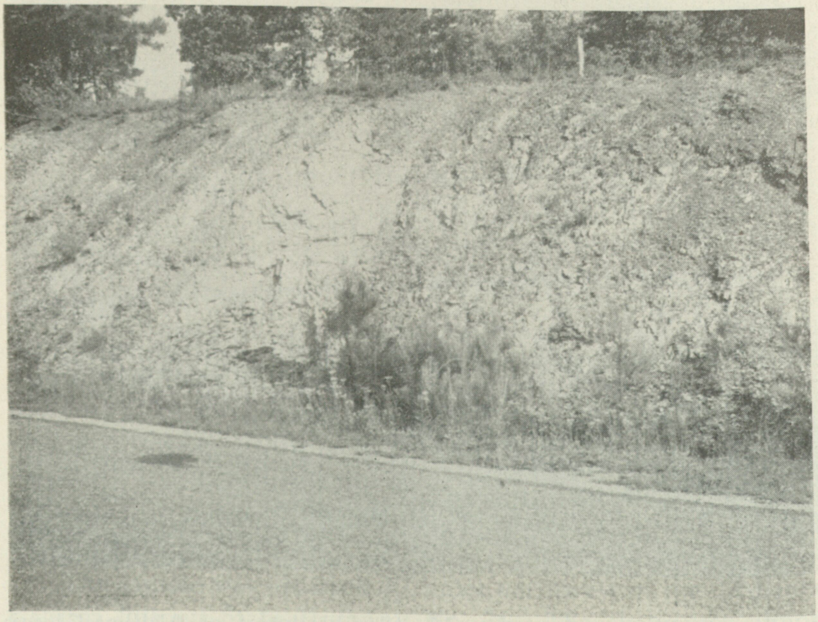


Fig. 5.—Weisner formation 2.8 miles northwest of Alabama-Georgia line on Alabama Highway 74, Cherokee County, Sample No. 83.

Drying behavior:

Linear drying shrinkage	2.4%
Volume drying shrinkage	6.9
Pore water	27.2
Shrinkage water	4.3
Water of plasticity	31.5
Drying defects	None noted

Transverse strength: 77 pounds per square inch.

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	45.8	2.45	0.8	Buff
06	40.9	10.8	3.7	Reddish buff
04	33.9	19.5	7.0	Reldish buff
02	25.7	28.8	10.7	Salmon
1	16.8	35.4	13.6	Light brownish red
3	12.1	37.7	14.6	Dark brownish red
5	8.3	38.6	15.0	Dark brownish red
7	1.5	39.1	15.2	Dark brownish red
9	1.6	36.4	14.0	Dark brownish red
11	16.4	30.0	11.2	Yellowish brown
13	23.0	23.1	8.4	Yellowish brown

P.C.E.: Cone 15-16

The material has a low dry strength, however, it can be used for ordinary structural clay products. The colors of the fired pieces are good.

CHILTON COUNTY

Sample 91. Phyllite

The sample was obtained 4.6 miles south of Shelby between Shelby and Clanton. It is pink on the surface and gray inside. The phyllite would not slake in water.

Geological formation: Waxahatchee slate of the Talladega series.

Working properties: The material was not plastic enough to use.

P.C.E.: Cone 14. This is not very accurate as it tended to bloat.

It is not believed that this phyllite is of value for ceramic use.

Sample 92. Schist

The sample was taken 6.8 miles north of Clanton and ½ of a mile north of the end of the pavement on the Clanton-Shelby road at the R. E. Jones property. It is a yellow weathered schist which slaked only slightly in water.

Geological formation: Talladega.

Working properties: The schist was not plastic enough to extrude from the machine.

P.C.E.: Cone 10-11. This is not accurate as the cones start to bloat.

It is not believed that this material is suitable for ceramic uses.

CLARKE COUNTY

Sample 74. Shale or Bedded Clay

The sample was collected from a road cut on U. S. Highway No. 43, 8.4 miles south of Dixons Mill and 2.6 miles north of the highway junction at Thomasville. It is gray in color and slakes as plates.

Geological formation: Hatchetigbee Clay from just above the Bashi marl.

Working properties: It did not work well and all of the bars cracked in drying.

Drying behavior:

Linear drying shrinkage	10.8%
Volume drying shrinkage	28.9
Pore water	25.2
Shrinkage water	35.5
Water of plasticity	60.7
Drying defects	Cracked in drying

P.C.E.: Cone 11.

The clay is hard when dry. Transverse cracks developed and the bars fell apart. It is not believed that this material is of value.

Sample 75. Shale or bedded clay

The sample was taken from a road cut on U. S. Highway No. 43 at Thomasville. It is 0.9 mile south of the road junction of State Highway No. 5 and U. S. Highway No. 43 at Thomasville. It is a light-gray iron stained clay which slakes readily, and consists primarily of illite and quartz.

Geological formation: Hatchetigbee

Working properties: Satisfactory

Drying behavior:

Linear drying shrinkage	23.8%
Volume drying shrinkage	55.6
Pore water	13.3
Shrinkage water	30.0
Water of plasticity	43.3
Drying defects	On account of high shrinkage, it must be dried with care

Transverse strength: 1010 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	30.75	5.4	1.9	Light tan
06	26.7	11.5	4.0	Light tan
04	22.0	17.4	6.2	Light tan
02	18.6	20.1	7.3	Buff
1	13.9	23.5	8.6	Buff
3	8.5	25.4	9.3	Light brown
5	8.8	25.7	9.5	Brown
7	1.9	26.9	10.0	Gray brown
9	1.4	23.1	8.4	Gray
11	22.7	10.0	3.5	Yellow gray

P.C.E.: Cone 15-16

The clay has a very high dry strength and consequently it would make a good bond. The P.C.E. is relatively high, however, the drying shrinkage is excessive. When fired, it has a very poor color.

CLEBURNE COUNTY

Sample 84. Shale or Bedded Sandy Clay

The sample was taken from a railroad cut 2.3 miles east of Palestine between Palestine, Alabama and Esom Hill, Georgia. There was 50 feet exposed. The material was very sandy and was variegated in pink and white colors. It slaked to a sandy mud.

Geological formation: Weisner

Working properties: Poor. It was extruded but the bars could not be handled when dry.

P.E.C.: Cone 15.

The material is not satisfactory for ceramic products as it is too sandy.

Sample 85. Shale or Bedded Sandy Clay

The sample was collected in a highway cut above sample No. 84. There were 30 feet exposed. This is a soft sandy shale in variegated pink and white colors. It slaked to a mud.

Geological formation: Weisner

Working properties: Poor as the material is too sandy.

Drying behavior:

Linear drying shrinkage	1.9%
Volume drying shrinkage	5.6
Pore water	27.65
Shrinkage water	3.6
Water of plasticity	31.1
Drying defects	Tended to crack

Transverse strength: Too weak for testing

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	45.4	—1.2	—.4	Light pinkish tan
06	40.45	7.55	2.6	Light pinkish tan
04	35.15	15.3	5.4	Light pinkish tan
02	28.8	22.25	8.0	Light pinkish tan
1	23.3	27.9	10.4	Brown with pink cast
3	18.15	32.35	12.2	Brown with pink cast
5	10.0	37.6	14.5	Brown with pink cast
7	7.1	38.5	15.0	Brown with pink cast
9	4.1	38.7	15.1	Brown with pink cast
11	14.5	32.1	12.2	Brown with pink cast
13	22.6	25.4	9.3	Brown

P.C.E.: Cone 15-16

The shale could be used for the manufacture of common brick, but is difficult to work. The shale has a high firing shrinkage considering the large silica content. The color of the fired pieces was poor.

Sample 86. Phyllite

The sample was taken from a road cut on State Highway No. 37, 1.2 miles south of De Armanville. There is an exposure of 200 feet. This is a gray micaceous phyllite and is soft. It did not slake in water.

Geological formation: Talladega

Working properties: It would not work because the water squeezed out of the phyllite and it became dry.

P.C.E.: Cone 11

The material is of no value by itself, however, it has some possibilities for coating other ceramic products.

Sample 87. Chlorite Schist

There was a narrow exposure at the same location as sample No. 86. It is a hard greenish-gray fresh schist which would not slake in water.

Geological formation: Hillabee schist

Working properties: It is non-plastic and would not work in the machine.

P.C.E.: Cone 7-8

The material is probably of no value for ceramic products.

Sample 88. Schist

The deposit is located on Skyway Drive about ½ mile southwest from the junction with State Highway No. 37. There is an exposure of about 100 feet. The schist is yellowish gray in color and would slake only slightly in water.

Geological formation: Talladega

Working properties: It would not mix satisfactorily with water and could not be run through the machine.

P.C.E.: Cone 13-14.

COLBERT COUNTY

Sample 15. Fire Clay

This is a black clay with a hackly fracture occurring in a bed 9 feet thick in a section of 40 feet of sandy shale and black clay with gravel above and below. It is on Highway No. 72 about half way up the hill on the west bank of the creek, west of Margerum and about half a mile east of the Mississippi-Alabama state line. When dry it has a gray color, is massive, and did not slake in water.

Geological formation: Tuscaloosa

Working properties: The plastic clay was rather stiff but came out of the machine soft. The working properties may be classed as fair.

Drying behavior:

Linear drying shrinkage	5.6%
Volume drying shrinkage	15.8
Pore water	21.1
Shrinkage water	9.3
Water of plasticity	30.4
Drying defects	None

Transverse strength: 288 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	45.35	0.2	0.07	White
06	44.25	1.8	0.6	Light pink
04	43.75	3.15	1.1	Light pink
02	43.2	3.7	1.2	Cream
1	43.1	3.9	1.4	Cream
3	43.1	4.0	1.4	Cream
5	43.3	4.5	1.5	Cream
7	41.6	5.35	1.8	Cream
9	41.0	4.2	1.4	Cream
11	41.0	2.8	0.9	Cream
13	41.3	0.7	0.2	Cream

P.C.E.: Cone 26

The clay is carbonaceous and the clay is not readily oxidized. The material is peculiar in that it has a very low firing shrinkage over the entire temperature range and maintains a high, rather uniform porosity. It shows some signs of over firing at cone 11. This is an interesting clay and may prove to be useful in the processing of insulating refractories. A slight red scum can be noticed on the fired pieces. This came from soluble iron sulfate in the clay. The clay is siliceous and has a very high pore water content.

Sample 103. Bedded Clay

The sample was taken from a road cut on the north side of U. S. Highway No. 72 at the top of the hill at the Mississippi-Alabama State line. It is a mixture of sandy and plastic shale which contains some mica. It slakes into a mud.

Geological formation: Tuscaloosa

Working properties: Very good

Drying behavior:

Linear drying shrinkage	6.6%
Volume drying shrinkage	18.6
Pore water	17.6
Shrinkage water	10.4
Water of plasticity	28.0
Drying defects	None noted

Transverse strength: 664 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	36.1	0.00	0.00	Buff
06	35.8	0.00	0.00	Buff
04	35.7	0.8	0.3	Buff
02	35.6	0.8	0.3	Reddish buff
1	35.0	1.2	0.4	Reddish buff
3	34.7	2.15	0.7	Reddish buff
5	34.15	2.8	0.9	Reddish buff
7	32.7	4.65	1.6	Reddish buff
9	29.5	7.5	2.6	Tan
11	28.1	8.7	3.0	Tan
13	25.1	10.9	3.8	Yellowish tan

P.C.E.: Cone 18-19

This is a peculiar clay in that the shrinkage is very low over the long firing range. Also, it has a very high dry strength for a sandy clay. The P.C.E. is too low for a high grade fire clay, but it may find use in siliceous cements.

Sample 104. Shale

The sample was taken from a road cut 9.6 miles west of Tuscumbia on U. S. Highway 72. It was selected from a limestone outcrop on the west side of the highway 1.3 miles east of Barton station. It is very calcareous and appears to be a mixture of shale and limestone.

Geological formation: Tuscumbia limestone

Working properties: It is non-plastic and cannot be extruded through the machine.

It is not believed that this material is of value.

CULLMAN COUNTY

Sample 30. Shale

The deposit is located about 6 miles south of Cullman on U. S. Highway No. 31. It is a yellow weathered shale which lies above a black shale. The same shale outcrops in Hanceville and Garden City. (See sample 33). It is a platy, soft, weathered shale and slakes easily.

Geological formation: Lower Pottsville

Working properties: Good

Drying behavior:

Linear drying shrinkage	8.1%
Volume drying shrinkage	22.3
Pore water	20.3
Shrinkage water	13.1
Water of plasticity	33.4
Drying defects	None noted

Transverse strength: 318 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	38.3	3.1	1.1	Buff
06	33.8	10.4	3.6	Buff
04	25.4	19.3	6.9	Salmon
02	20.5	24.2	8.8	Salmon
1	16.0	27.7	10.2	Light brownish red
3	11.2	30.3	11.3	Brownish red
5	1.9	32.1	12.1	Reddish brown
7	0.15	32.9	12.5	Reddish brown
9	0.3	32.2	12.1	Chocolate
11	3.1	25.5	9.3	Gun metal

P.C.E.: Cone 16-17

The shale started to overfire at cone 9 but overfiring did not become serious until cone 11 was reached. It has a fairly satisfactory firing range and is refractory for a shale as the P.C.E. is high. This shale should be satisfactory for practically all types of structural clay products, and might be very valuable for the manufacture of sewer pipe. The dry transverse strength is satisfactory. The colors of the fired pieces are fair.

Sample 33. Shale

This is a sample of black shale taken from a road cut 6 miles south of Cullman on U. S. Highway 31. The stratum is 10 feet thick to the bottom of the cut. It is a hard carbonaceous shale with a gray color when dry. It slakes slightly in water. Same locality as sample 30.

Geological formation: Lower Pottsville

Working properties: Was plastic when ground and mixed with water. Very satisfactory.

Drying behavior:

Linear drying shrinkage	4.3%
Volume drying shrinkage	12.3
Pore water	6.6
Shrinkage water	16.9
Water of plasticity	23.5
Drying defects	None

Transverse strength: 333 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	30.1	9.1	3.1	Buff
06	26.25	14.2	5.0	Buff
04	14.3	24.9	9.0	Salmon
02	8.65	27.9	10.3	Brownish red
1	3.8	28.2	10.5	Brownish red
3	3.2	29.1	10.8	Dark reddish brown
5	4.2	29.0	10.8	Dark reddish brown
7	3.6	28.1	10.5	Chocolate
9	10.35	19.65	7.1	Gun metal

P.C.E.: Cone 15

The shale overfires at cone 9 but is fairly refractory as shown by its P.C.E. value. It has a good firing range and should be useful for the manufacture of many structural clay products if zero porosity is not required. It would need some care in oxidation and contains some lime. The colors of the fired pieces are fair.

DeKALB COUNTY.

Sample 64. Shale

The sample was taken from a deposit 4.3 miles west of Fort Payne, east of Sand Mountain on the Scottsboro-Fort Payne Highway (State Highway No. 35). The deposit has a vertical dip and is made up of strata of various colors and textures. This sample is a hard black carbonaceous shale and which would not slake and could not be extruded by the auger machine.

Geological formation: Red Mountain.

P.C.E.: Cone 16.

It is not believed to be of value.

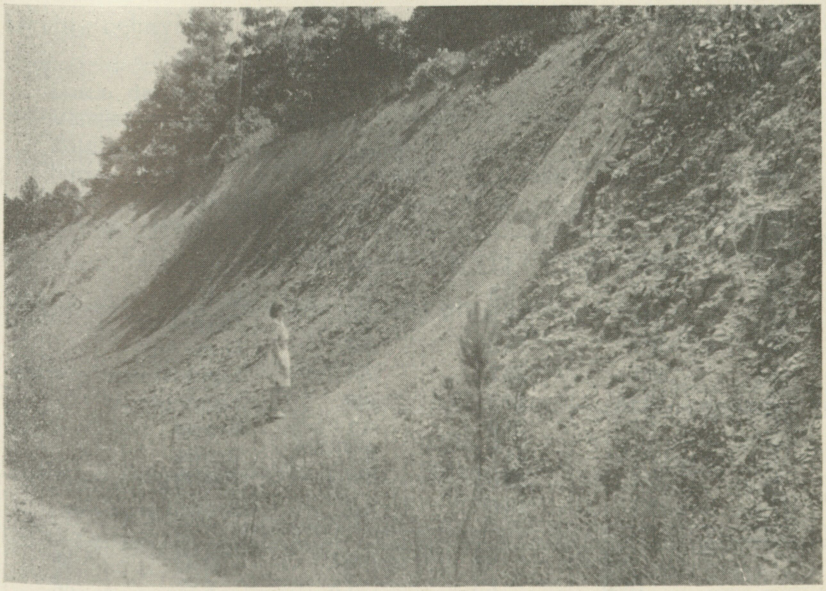


Fig. 6.—Red Mountain formation 4.3 miles west of Ft. Payne on Scottsboro highway on east side of Sand Mountain, DeKalb County. Sample No. 64.

Sample 65. Shale

This sample was taken 100 feet east of sample number 64. It is green in color and slakes readily into small plates.

Geological formation: Red Mountain

Working properties: Very good

Drying behavior:

Linear drying shrinkage	3.6%
Volume drying shrinkage	10.3
Pore water	16.5
Shrinkage water	5.7
Water of plasticity	22.2
Drying defects	None noted

Transverse strength: 258 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	29.1	4.1	1.4	Buff
06	26.7	7.8	2.7	Buff
04	23.7	11.5	4.0	Deep buff
02	18.6	16.8	6.0	Deep buff
1	14.2	20.7	7.4	Light brown
3	10.45	24.4	8.9	Light brown
5	8.0	25.0	9.1	Brown
7	3.25	24.5	8.9	Brown
9	2.1	22.0	7.9	Yellowish brown
11	18.5	13.0	4.5	Brownish yellow

P.C.E.: Cone 16.

The shale could be used, although it has a rather short vitrification range. However, it would be rather difficult to mine as the deposit has a vertical dip. The P.C.E. is high for a shale. The color of the fired shale is poor.

ETOWAH COUNTY

Sample 66. Shale

The sample was taken from the storage bin at the Agricola Brick Company plant on the Alabama, Georgia, and Tennessee Railroad, 4.0 miles north of Gadsden. The pit is at the base of Lookout Mountain 100 yards west of the plant. The shale is overlain by a thick bed of sandstone. The shale is yellow, indicating weathering and slakes to a mud.

Geological formation: Pottsville

Working properties: Good, and it is very plastic.

Drying behavior:

Linear drying shrinkage	10.8%
Volume drying shrinkage	29.0
Pore water	14.0
Shrinkage water	15.2
Water of plasticity	29.2
Drying defects	None noted

Transverse strength: 604 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	30.9	3.0	1.0	Buff
06	27.8	6.7	2.3	Buff
04	25.8	9.7	3.3	Salmon
02	21.1	14.3	5.0	Salmon
1	16.05	18.1	6.4	Light brownish red
3	14.3	19.9	7.2	Light brownish red
5	13.1	20.6	7.4	Light brownish red
7	11.2	21.3	7.7	Dark brownish red
9	8.7	21.7	7.8	Dark brownish red
11	16.2	14.5	5.1	Chocolate

P.C.E.: Cone 14

This shale had the highest dry strength of any of the regular Pottsville shales tested. Consequently, it should be easy to handle when dry. It does not reach a low porosity but on the other hand it does not tend to overfire until the temperature passes cone 7. It is suitable for most shale products except when a highly vitrified body is desired. The color of the fired shale is good.

FAYETTE COUNTY

Sample 28. Shale

This is a bed of shale from a bluff 25 to 30 feet high on the west side of U. S. Highway 43. There is a bed of hard sandstone in the middle of the bluff. The locality is 18 miles north of

Samantha and .8 mile south of the railroad station at Bankston. The color is gray and it does not slake. It is also very sandy.

Geological formation: Pottsville

Working properties: Poor

Drying behavior:

Linear drying shrinkage	2.0%
Volume drying shrinkage	5.8
Pore water	16.8
Shrinkage water	3.1
Water of plasticity	19.9
Drying defects	Tended to crack in drying

Transverse strength: 162 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	35.2	—0.75	—0.3	Buff
06	33.2	1.9	0.6	Light salmon
04	28.1	3.3	1.2	Salmon
02	22.5	14.2	5.0	Light brownish red
1	21.2	15.25	5.4	Brownish red
3	16.35	19.6	7.1	Brownish red
5	14.4	21.15	7.7	Deep brownish red
7	10.3	23.35	8.6	Chocolate
9	16.0	17.1	6.1	Gun metal

P.C.E.: Cone 12

The shale overfired at cone 9 and never reached a low porosity. This could be used for common brick, but it is not a valuable shale. It tends to crack, but has a fair color.

Sample 99. Shale

The sample was taken from a road cut on State Highway No. 18 about 1 mile west of Berry on the paved road to Tuscaloosa. There is an exposure of about 18 feet. This is a hard massive shale which slakes readily in water. It is rather carbonaceous and gray in color.

Geological formation: Pottsville

Working properties: Very good

Drying behavior:

Linear drying shrinkage	3.1%
Volume drying shrinkage	9.05
Pore water	14.4
Shrinkage water	4.6
Water of plasticity	19.0
Drying defects	None noted

Transverse strength: 387 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	50.5	3.3	1.1	Salmon
06	23.45	12.2	4.2	Dark salmon
04	16.75	18.1	6.4	Dark salmon
02	4.9	25.95	9.5	Brownish red
1	0.0	30.1	11.3	Brownish red
3	0.25	27.8	10.3	Brownish red
5	0.25	26.0	9.5	Brownish red
7	0.25	17.9	6.4	Brownish red

P.C.E.: Cone 7

The shale has a very low P.C.E. value. It has a minimum porosity at cone 1, which is low, and starts to overfire at cone 3. It can be used but some care would be necessary in firing. Very good color, predominantly red, at cones 02, 1, 3, 5.

FRANKLIN COUNTY

Sample 14. Shale

The sample was collected opposite an old filling station on U. S. Highway No. 43, 5.5 miles north of Phil Campbell, and lies about half way down the Pottsville escarpment. It is a hard fissile shale with a light gray to green color and slakes as plates.

Geological formation: Pottsville

Working properties: The shale worked perfectly in the auger machine.

Drying behavior:

Linear drying shrinkage	6.0%
Volume drying shrinkage	16.9
Pore water	13.5
Shrinkage water	8.9
Water of plasticity	22.4
Drying defects	None noted

Transverse strength: 412 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	28.9	4.45	1.6	Reddish yellow
06	24.4	10.3	3.6	Reddish yellow
04	22.0	13.1	4.6	Reddish yellow
02	14.15	20.3	7.3	Dark salmon
1	11.3	21.5	7.8	Brownish red
3	7.8	23.5	8.6	Reddish brown
5	7.0	23.5	8.6	Light gun metal
7	6.1	22.9	8.3	Light gun metal
9	9.7	19.7	7.1	Gray
11	18.5	8.3	2.8	Yellowish gray

P.C.E.: Cone 12-13

The clay starts to overfire at cone 7. The carbon is removed slowly in oxidation. The shale has a fairly high dry strength and there would be no difficulty in forming, however, it contains considerable soluble magnesium salts which might lead to scumming. In addition, it never reached a low porosity. It could be used for the manufacture of common brick, and might prove to be very successful for the manufacture of a light-weight concrete aggregate.

Sample 16. Shale

This deposit is located on U. S. Highway No. 43 on the north-facing slope of the Pottsville escarpment 5.3 miles north of Phil Campbell near the top of the escarpment, and should be considered in its relation to sample number 14. The clay is fissile and has a gray color and slakes readily.

Geological formation: Pottsville

Working properties: Good

Drying behavior:

Linear drying shrinkage	7.8%
Volume drying shrinkage	21.5
Pore water	19.1
Shrinkage water	12.2
Water of plasticity	31.3
Drying defects	None noted

Transverse strength: 325 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	36.0	6.0	2.0	Light cream
06	31.65	12.5	4.4	Cream
04	28.2	19.9	7.2	Cream
02	17.8	25.8	9.5	Buff
1	16.35	26.6	9.8	Buff
3	11.45	28.9	10.7	Yellowish gray
5	9.4	29.6	11.0	Yellowish gray
7	1.5	31.45	11.8	Gray
9	0.15	31.5	11.8	Gray
11	3.9	26.2	9.7	Gray
13	18.0	17.9	6.4	Gray

P.C.E.: Cone 18.

While the clay has the structure of a shale, it fires to a cream color. This is unusual as most shales fire to a red color. This clay might be valuable for use in making sewer pipe as it is very refractory for its type and works well in the auger machine. There is a sudden drop in the porosity between cones 5 and 7 but no corresponding change in the volume shrinkage. It does not oxidize very readily. This is an unusual type of clay and may be of value.

JACKSON COUNTY

Sample 60. Shale

The sample was collected from a road cut on State Highway No. 32 which is the Guntersville-Scottsboro Highway, about ¼ mile north of a small bridge and 6.5 miles south of Scottsboro. There is an exposure of 40-50 feet of shale. It is weathered, yellow in color, and slakes readily.

Geological formation: Red Mountain

Working properties: Good

Drying behavior:

Linear drying shrinkage	5.9%
Volume drying shrinkage	16.7
Pore water	18.5
Shrinkage water	9.3
Water of plasticity	27.8
Drying defects	None noted

Transverse strength: 301 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	33.4	5.75	2.0	Light salmon
06	27.4	12.6	4.4	Salmon
04	21.3	19.1	6.9	Light brownish red
02	15.8	23.9	8.7	Light brownish red
1	11.9	26.8	9.9	Light brownish red
3	8.1	29.3	11.0	Brownish red
5	1.8	29.4	11.0	Brownish red
7	0.55	26.55	9.8	Brownish red
9	15.8	21.8	7.9	Brownish red
11	25.8	7.7	2.6	Chocolate

P.C.E.: Cone 14

This shale does not have a long firing range and starts to overfire at its minimum porosity at cone 7. It oxidizes readily and has good dry strength. When fired, it has a very good color.

Sample 61. Shale

The shale outcrops along the Tennessee River, and the sample was taken at the bridge on State Highway No. 35, which is known as the Scottsboro-Fort Payne Highway. The bridge is 4.1 miles east of Scottsboro. There is an exposure of 40-50 feet of shale overlying and dipping 10° east toward the river. It is a hard weathered shale, yellow in color which slakes as large fragments.

Geological formation: Gasper

Working properties: Good

Drying behavior:

Linear drying shrinkage	5.0%
Volume drying shrinkage	14.0
Pore water	16.8
Shrinkage water	7.6
Water of plasticity	24.4
Drying defects	None noted

Transverse strength: 238 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	28.3	8.7	3.0	Salmon
06	24.7	12.9	4.5	Salmon
04	18.1	19.05	6.8	Salmon
02	12.35	23.25	8.4	Light brownish red
1	6.9	25.7	9.4	Light brownish red
3	4.5	26.7	9.8	Brownish red
5	2.8	26.5	9.8	Brownish red
7	0.2	4.7	0.6	Brownish red

P.C.E.: Cone 12

The shale tends to bloat at cone 7 and does not have a long firing range. It has a good color when fired.

Sample 62. Shale

This sample came from the same location as sample No. 61. It is loose shale which had crumbled and rolled down the cliff. It is the yellow shale underlying the Bangor limestone which in turn underlies the Pennington and Pottsville formations on Sand

Mountain on the east side of the Tennessee River. It is a soft weathered shale occurring as small platy fragments. It slaked to a slight extent.

Geological formation: Gasper

Working properties: Good

Drying behavior:

Linear drying shrinkage	5.2%
Volume drying shrinkage	14.7
Pore water	17.2
Shrinkage water	7.6
Water of plasticity	24.8
Drying defects	None noted

Transverse strength: 278 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	29.1	7.1	2.4	Buff
06	21.25	16.2	5.7	Salmon
04	14.6	21.0	7.6	Light brownish red
02	1.55	27.8	10.3	Light brownish red
1	0.2	28.4	10.6	Reddish brown
3	0.3	26.3	9.7	Reddish brown
5	0.3	22.2	8.0	Reddish brown

P.C.E.: Cone 14

Overfiring started at cone 3 and bloating was in evidence at cone 5. The shale consequently overfires at a low temperature and has a short vitrification range. It could be used for common brick. Very fine color.

Sample 63. Shale

The shale occurs beneath 40 feet or more of hard sandstone near the top of Sand Mountain on the east side of the Tennessee

River on the Scottsboro-Fort Payne Highway (State Highway No. 35), 21.3 miles west of Fort Payne. It is a hard carbonaceous shale, dark gray in color when dry and slakes as plates.

Geological formation: Pottsville

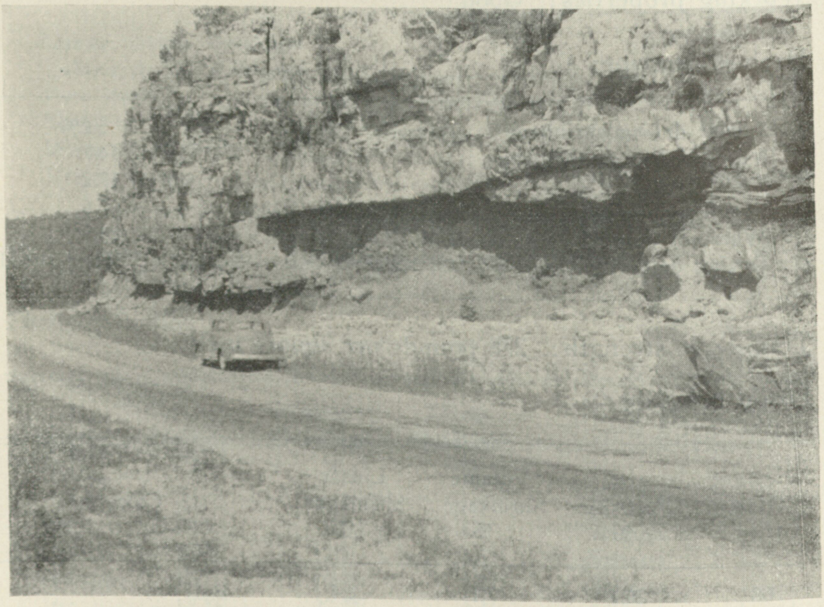


Fig. 7.—Pottsville black shale beneath massive sandstone 21.3 miles west of Ft. Payne on Scottsboro highway on west side of Sand Mountain overlooking Tennessee River, Jackson County. Sample No. 63.

Working properties: Good

Drying behavior:

Linear drying shrinkage	3.7%
Volume drying shrinkage	10.8
Pore water	16.3
Shrinkage water	5.6
Water of plasticity	21.9
Drying defects	None noted

Transverse strength: 248 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	35.1	4.9	1.7	Buff
06	28.1	14.3	5.0	Salmon
04	22.0	20.5	7.4	Salmon
02	15.5	25.6	9.4	Brownish red
1	12.5	27.3	10.1	Brownish red
3	9.15	28.3	10.5	Brownish red
5	6.9	29.1	10.8	Deep brownish red
7	1.5	28.9	10.7	Deep brownish red
9	2.0	26.8	9.9	Chocolate
11	15.9	16.3	5.8	Chocolate

P.C.E.: Cone 9-10. Not exact as the shale tends to bloat when fusion tests are made.

The shale could be used for making brick, however, chemical tests show the presence of considerable soluble sulfates and chlorides of calcium and magnesium, consequently scumming would be expected. It has a good color when fired.

JEFFERSON COUNTY

Sample 1. Shale

The sample was secured at the plant of the Stephenson Brick Company at Lovick, Alabama, and consisted of ten standard size unfired brick. These were made from a mixture of weathered and unweathered shale and were yellow-brown in color.

Geological formation: Pottsville

Working properties: Good

Drying behavior:

Linear drying shrinkage	4.7%
Volume drying shrinkage	13.5
Pore water	15.6
Shrinkage water	7.4
Water of plasticity	23.0
Drying defects	None noted

Transverse strength: 339 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	31.6	4.7	1.6	Light salmon
06	27.2	10.4	3.6	Salmon
04	23.4	14.6	5.1	Salmon
02	11.3	22.9	8.3	Brownish red
1	10.2	25.0	9.1	Brownish red
3	2.2	26.3	9.7	Brownish red
5	2.4	26.1	9.6	Brownish red
7	1.6	26.1	9.6	Reddish brown
9	9.8	19.5	7.0	Deep reddish brown
11	16.9	12.6	4.4	Chocolate

P.C.E.: Cone 14.

The clay bloats at cone 9. It oxidizes readily, and has a safe firing range. The shale is used for the manufacture of hollow block, face, and common brick.

Sample 2. Shale

The sample was collected from the pit of the Stephenson Brick Company at Lovick, Alabama, and was from the unweathered strata. It is a hard carbonaceous shale which does not slake readily and is fine-grained.

Geological formation: Pottsville

The chemical analysis of this material is as follows:

Ignition loss	8.70%
SiO_2	55.08
Al_2O_3	19.63
Fe_2O_3	8.38
TiO_2	0.97
CaO	0.28
MgO	2.05
Alkalies as Na_2O	2.67
	97.73

Working properties: An attempt was made to process —10 mesh material, but it was found necessary to grind to —20 mesh as the clay was not very plastic.

Drying behavior:

Linear drying shrinkage	3.1%
Volume drying shrinkage	9.0
Pore water	14.65
Shrinkage water	4.2
Water of plasticity	18.85
Drying defects	None noted

Transverse strength: 297 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	30.2	5.5	1.9	Light salmon
06	24.75	12.2	4.2	Light salmon
04	17.60	19.35	6.9	Salmon
02	2.5	25.0	9.1	Brownish red
1	1.3	25.7	9.4	Brownish red
3	1.4	26.3	9.7	Brownish red
5	1.3	26.8	9.9	Dark brownish red
7	9.3	14.7	5.2	Chocolate

P.C.E.: Cone 12-13

The clay does not oxidize readily on account of its high carbon content and has a sudden decrease in porosity and increase in volume shrinkage at cone 02. It is not a desirable material for structural clay products when used alone, however, it may be valuable for the production of a light-weight aggregate and tends to bloat at cone 7. The shale fires to a good color.

Sample 3. Fire clay

The sample was obtained from the Harbison-Walker Refractories Company at Bessemer, Alabama. The clay was mined by the Black Creek Coal Company at Thermal, Alabama (near Trafford). The clay is black in color and showed "slickensides" characteristic of the underclays below coal seams. It is very carbonaceous and slakes as angular fragments.

Geological formation: Pottsville

Working properties: Fair

Drying behavior:

Linear drying shrinkage	3.7%
Volume drying shrinkage	10.8
Pore water	10.2
Shrinkage water	5.1
Water of plasticity	15.3
Drying defects	None noted

Transverse strength: 462 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	24.2	5.15	1.8	Cream
06	21.7	7.95	2.7	Cream
04	18.1	11.85	4.1	Cream
02	14.1	13.95	4.9	Dark cream
1	14.3	13.75	4.8	Dark cream
3	9.3	15.6	5.5	Tan
5	2.0	15.8	5.6	Tan
7	4.8	16.4	5.8	Tan
9	3.75	15.65	5.5	Light yellow gray
11	4.9	9.8	3.4	Light yellow gray
13	8.9	8.7	3.0	Light yellow gray

P.C.E.: Cone 27.

The clay showed marked bloating when fired at cone 11. It was fairly easy to oxidize. A clay of this type is suitable for the manufacture of ladle brick and refractories where a low grade fire clay can be used. It could be utilized in the manufacture of buff building brick and other structural clay products. In minor amounts it can be mixed with more refractory materials for the manufacture of high grade refractories. The transverse strength is high indicating that it has good bonding properties.

Sample 5. Fire clay

The sample was collected at the plant of the Dixie Fire Brick Company plant near Kimberly, which is 20 miles north of Birmingham. The fire clay was obtained from the No. 2 Dixie Mine which is located 3 miles northwest of the plant. The clay is rather massive, is carbonaceous, and blue back in color. It slakes only slightly in water.

Geological formation: Pottsville

Working properties: Satisfactory

Drying behavior:

Linear drying shrinkage	3.5%
Volume drying shrinkage	10.2
Pore water	9.5
Shrinkage water	5.0
Water of plasticity	14.5
Drying defects	None noted

Transverse strength: 403 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	24.5	3.0	1.1	Cream through tans to light gray at cone 9
06	23.2	4.55	1.6	
04	20.9	7.75	2.7	
02	19.25	9.05	3.1	
1	18.2	9.5	3.3	
3	15.8	11.1	3.8	
5	14.0	11.9	4.1	
7	13.3	11.9	4.1	
9	11.6	11.3	3.9	
11	14.0	6.5	2.2	Light gray

P.C.E.: Cone 23

The clay can be used for refractories which do not have to meet any severe service conditions. It has fair dry strength, and consequently some bonding properties. It overfires seriously at cone 11. It may be classed as an open firing clay, because the porosity remains comparatively high throughout its firing range. The shrinkage in firing is very low. It fires to a good color.

Sample 6. Shale

The sample was obtained at the Birmingham Clay Products Company plant in North Birmingham. The factory is on 24th Street, one mile beyond 33rd Avenue. The sample consisted of several unfired brick. The sample was a mixture of shales from various strata and contained both weathered and unweathered material. It shows a trace of soluble sulfates, and gives a test for lime.

Geological formation: Pottsville

Working properties: It did not work very satisfactorily in the auger machine when ground to pass 10 mesh, however, it was very satisfactory when ground to pass 20 mesh.

Drying behavior:

Linear drying shrinkage	3.6%
Volume drying shrinkage	10.5
Pore water	16.8
Shrinkage water	6.2
Water of plasticity	23.0
Drying defects	None noted

Transverse strength: (Data on —20 mesh material) 305 pounds per square inch.

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	30.9	6.7	2.3	Light salmon
06	24.3	14.6	5.1	Salmon
04	17.8	21.1	7.6	Salmon
02	2.3	28.3	10.5	Brownish red
1	0.3	29.2	10.9	Reddish brown
3	0.3	28.7	10.7	Reddish brown
5	0.15	28.5	10.6	Reddish brown
7	12.9	12.8	4.5	Chocolate

P.C.E.: Cone 13

The shale oxidizes fairly well, but if the brick are fired too rapidly through the oxidation period they will have a black core.

The fired test pieces have small pits on the surfaces which are most probably due to the expansion of iron minerals during the oxidation period. The shale has a very satisfactory firing range, as the porosity is low and shrinkage remains practically constant between cones 02 and 5. The shale is used for the manufacture of brick and should be satisfactory for many other structural clay products. It tends to bloat at cone 7. A small amount of scum is present on the fired test pieces.

Sample 7. Shale

Sample of mixed shale, 50% hard blue, 45% yellow weathered, 5% plastic. The pit is located 6 miles from Bessemer beyond Jonesboro at Sargon on the Southern Railroad. The sample was collected at the plant of the National Fireproofing Company in North Birmingham. The clay was obtained in the ground condition.

Geological formation: Pottsville

Working properties: The clay was rather soft when put into the auger machine but worked very satisfactorily.

Drying behavior:

Linear drying shrinkage	3.9%
Volume drying shrinkage	11.0
Pore water	11.8
Shrinkage water	5.3
Water of plasticity	17.1
Drying defects	None noted

Transverse strength: 630 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	26.7	4.4	1.5	Light salmon
06	23.9	7.45	2.6	Light salmon
04	17.0	15.2	5.3	Salmon
02	13.05	18.0	6.4	Brownish red
1	10.05	19.4	7.0	Brownish red
3	2.4	21.2	7.6	Brownish red
5	1.15	20.45	7.4	Reddish brown
7	0.25	19.8	7.1	Dark reddish brown
9	15.7	5.7	1.9	Chocolate

P.C.E.: Cone 13

The clay has a sufficient firing range for good vitrification, and has very high dry strength, which makes for easy handling of unfired ware. The mixture of shales is being used for the manufacture of roofing tile, but its use could be expanded to other structural clay products. It overfires at cone 7.

Sample 8. Shale

This is a sample of mixed shale from the Watkins Brick Company. The plant and pit are located 1 mile west of Ensley on 19th Street, one and one-half miles west of Avenue I, Ensley, Alabama. The sample had previously been ground and was taken from the bins. It was yellow-brown in color and included some weathered shale.

Geological formation: Pottsville

Working properties: It worked fairly well in the auger machine.

Drying behavior:

Linear drying shrinkage	2.8%
Volume drying shrinkage	8.30
Pore water	16.6
Shrinkage water	4.5
Water of plasticity	21.1
Drying defects	None noted

Transverse strength: 292 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	31.6	5.2	1.8	Light salmon
06	29.0	8.7	3.0	Salmon
04	22.9	15.5	5.5	Salmon
02	13.1	24.0	8.7	Dark salmon
1	8.6	26.8	9.9	Brownish red
3	0.2	28.4	10.5	Reddish brown
5	0.3	28.6	10.6	Reddish brown
7	0.6	24.0	8.7	Dark reddish brown

P.C.E.: Cone 12-13

The clay has a comparatively short vitrification range, but is fired successfully in periodic kilns. It oxidizes without difficulty. This material has been used successfully for the manufacture of brick, and its use could be extended to other structural clay products. It fires to a satisfactory color.

Sample 10. Shale

The sample was secured at the plant of the W. S. Dickey Clay Manufacturing Company in Birmingham, and was mined from a pit near Littleton, Alabama. The pit is less than a quarter of a mile north of the bend in the Warrior River. It is shipped from Kilgore on the L. & N. R. R. The shale was bluish gray in color, and was obtained in the ground condition.

Geological formation: Pottsville

Working properties: No difficulties in processing

Drying behavior:

Linear drying shrinkage	3.0%
Volume drying shrinkage	8.2
Pore water	16.2
Shrinkage water	4.4
Water of plasticity	20.6
Drying defects	None noted

Transverse strength: 306 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	32.4	5.2	1.8	Light salmon
06	26.2	12.7	4.5	Light salmon
04	25.0	14.55	5.1	Salmon
02	7.3	27.90	10.4	Brownish red
1	0.6	29.2	10.9	Brownish red
3	0.0	29.9	11.2	Deep brownish red
5	0.3	29.8	11.2	Deep brownish red
7	0.0	25.6	9.4	Very deep brownish red
9	15.8	13.7	4.8	Chocolate

P.C.E.: Cone 12-13

The clay tends to start to overfire at cone 7 and bloats at cone 9. However, it has a fairly long vitrification range. The sharp drop in porosity and increase in shrinkage between cones 04 and 02 is very noticeable. Oxidation does not progress rapidly. This shale should be useful for structural clay products other than sewer pipe. It is mixed with fire clay from Lehigh, Alabama (Sample No. 9) for use in the manufacture of sewer pipe. When fired alone it has a very good rich color.

Sample 18. Shale

This is a gray shale beneath a sandstone in a road cut on the north side of the road, 1.2 miles west of Graysville on the paved road to Flat Top and West Jefferson School. The shale bed is 12-14 feet thick and overlies a seam of coal about four feet thick. The shale has a fissile structure and is soft and very sandy. It slakes only slightly when placed in water.

Geological formation: Pottsville

Working properties: The clay as placed in the mill was stiff, but came out soft.

Drying behavior:

Linear drying shrinkage	3. %
Volume drying shrinkage	8.5
Pore water	16.2
Shrinkage water	4.6
Water of plasticity	20.8
Drying defects	None noted

Transverse strength: 253 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	33.5	1.0	0.3	Reddish tan
06	30.5	5.65	2.0	Salmon
04	27.6	9.0	3.1	Salmon
02	22.0	14.9	5.2	Dark salmon
1	18.4	17.8	6.3	Brownish red
3	13.0	22.0	8.0	Brownish red
5	13.4	22.1	8.0	Brownish red
7	8.35	24.7	9.0	Deep brownish red
9	10.7	20.0	7.2	Chocolate

P.C.E.: Cone 14

The shale started to overfire at cone 9 and never reached a low porosity. It does not readily oxidize. This shale is not satisfactory for the manufacture of vitrified shale products. It fires to a fair color.

Sample 19. Shale

The shale is present in a road cut about .7 mile northwest of Adamsville and 1.6 miles south of Graysville on U. S. Highway 78. It is a rather hard fissile shale, gray in color, and slakes only slightly when placed in water.

Geological formation: Pottsville

Working properties: Very good

Drying behavior:

Linear drying shrinkage	3.7%
Volume drying shrinkage	10.5
Pore water	18.6
Shrinkage water	6.1
Water of plasticity	24.7
Drying defects	None noted

Transverse strength: 252 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	34.1	5.0	1.7	Cream
06	30.3	11.55	4.0	Cream with red tint
04	22.5	18.4	6.6	Salmon
02	14.7	25.2	9.3	Dark salmon
1	7.2	29.05	10.9	Brownish red
3	0.3	31.2	11.8	Brownish red
5	0.4	31.3	11.8	Brownish red
7	0.3	30.0	11.2	Deep brownish red
9	10.2	17.0	6.0	Dark brown
11	18.0	10.4	3.6	Gun metal with yellow cast

P.C.E.: Cone 14.

This is a very satisfactory shale for the manufacture of vitrified clay products as it has a long vitrification range. It would need some care in oxidation. It fires to a fair color.

Sample 20. Shale

The sample was obtained from a bluff of shale about 30 feet thick on the road from Praco to Flat Creek, and 0.2 mile north of the forks of the road leading to Labuca. The shale is yellow in color due to limonite and is a fairly massive soft shale. It is very sandy and slakes well.

Geological formation: Pottsville

Working properties: It is too sandy to work satisfactorily.

Drying behavior:

Linear drying shrinkage	2.8%
Volume drying shrinkage	7.9
Pore water	8.2
Shrinkage water	3.9
Water of plasticity	12.1
Drying defects	None noted

Transverse strength: 171 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	34.4	1.5	0.6	Reddish cream
06	33.0	4.0	1.4	Reddish cream
04	28.55	9.1	3.1	Salmon
02	24.35	13.8	4.9	Light brownish red
1	21.6	16.3	5.8	Light brownish red
3	17.95	19.1	6.9	Light brownish red
5	18.0	19.5	7.0	Light brownish red
7	10.9	24.4	8.9	Brownish red
9	9.5	24.0	8.7	Dark brownish red

P.C.E.: Cone 15

The clay never reached a low porosity during the firing, and the test bars stuck together at cone 9. This shale would be of low value for the manufacture of ceramic products. It has a good color when fired.

Sample 21. Impure fire clay

The clay was taken from beneath a four foot coal seam in a road cut on the road to Flat Creek, .6 mile west of West Jefferson

School. The clay bed is about 4 feet thick. The clay is variegated red and black in color and has the general appearance of a fire clay with the customary "slickensides." It slaked well and fell apart.

Geological formation: Pottsville

Working properties: Very good

Drying behavior:

Linear drying shrinkage	5.8%
Volume drying shrinkage	16.4
Pore water	28.3
Shrinkage water	9.8
Water of plasticity	38.1
Drying defects	None noted

Transverse strength: 313 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	37.2	2.8	1.0	Pinkish cream
06	33.5	8.75	3.1	Pinkish cream
04	22.4	21.5	7.8	Buff
02	9.8	29.8	11.0	Salmon
1	2.9	31.1	11.7	Brownish red
3	0.2	34.2	13.0	Reddish brown
5	0.0	34.4	13.1	Reddish brown
7	0.0	33.9	12.9	Brownish gray
9	1.9	26.0	9.6	Gray
11	8.2	15.8	5.6	Yellow gray

P.C.E.: Cone 16-17

The clay has a rather peculiar firing behavior between cones 04 and 02, with both sudden porosity and volume shrinkage changes. It fires to a vitrified body and has a fairly good vitrification range. The fusion point is not satisfactory for fire brick, but the clay might be useful for the manufacture of sewer pipe. The color is not particularly pleasing.

Sample 31. Shale

The sample was selected from the east side of the road on U. S. Highway No. 31, 29 miles south of Cullman, and 2 miles north of Warrior, Alabama. It has a light yellowish green color when wet, and makes up a bluff 15 feet wide. When dry it has a bluish color. It is fairly hard, but slakes in water.

Geological formation: Pottsville

The chemical analysis of the shale is as follows:

Ignition loss	7.09%
SiO_2	56.82
Al_2O_3	20.77
Fe_2O_3	7.22
TiO_2	0.94
CaO	None
MgO	1.55
Alkalies as Na_2O	5.06
	99.45

Working properties: Good

Drying behavior:

Linear drying shrinkage	4.03
Volume drying shrinkage	12.3
Pore water	19.6
Shrinkage water	6.9
Water of plasticity	26.5
Drying defects	None

Transverse strength: 364 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	34.2	5.9	2.1	Buff
06	28.2	13.6	4.8	Light salmon
04	15.3	25.4	9.3	Salmon
02	3.9	31.7	12.0	Light brownish red
1	0.1	33.9	12.9	Brownish red
3	0.0	33.0	12.5	Brownish red
5	0.3	31.85	12.0	Deep brownish red
7	0.3	25.0	9.2	Deep brownish red
9	12.0	16.8	6.0	Chocolate

P.C.E.: Cone 15

This is a particularly good shale as it has a good firing range and is suited for the manufacture of vitrified shale products. It has a sufficient strength in the dry condition to be easily handled and is refractory for a shale. It is also readily available. It has a very deep brownish red color when fired.

Sample 32. Shale

The sample was taken from a bluff of shale 15 feet high located on U. S. Highway 31, 7 miles south of Warrior, Alabama. This is a hard fissile shale partly weathered. It slaked slightly in water. It has a gray brown color.

Geological formation: Pottsville

Working properties: It was so sandy that it could not be extruded from the machine.

The P.C.E. is below cone 7 and the fused color is a light brown. It fuses to a smooth glass and it might be satisfactory as a natural glaze.

Sample 39. Shale

The sample was selected from a road cut on U. S. Highway

No. 31 about ½ mile north of the Cahaba River on the east side of the road. The shale exposure is 12 feet to the top of the road cut. It is a fairly soft fissile shale weathered to a light brown color. It slaked as plates.

Geological Formation: Pottsville

Working properties: Very good

Drying behavior:

Linear drying shrinkage	4.3%
Volume drying shrinkage	12.3
Pore water	23.2
Shrinkage water	6.9
Water of plasticity	30.1
Drying defects	None

Transverse strength: 212 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	39.1	4.0	1.4	Light buff
06	34.9	12.0	4.2	Buff
04	26.25	20.7	7.5	Salmon
02	14.3	30.3	11.4	Light brownish red
1	9.1	33.5	12.8	Light brownish red
3	0.0	37.4	14.5	Dark brownish red
5	0.3	37.1	14.3	Dark brownish red
7	0.15	36.0	13.9	Dark brownish red
9	0.3	34.0	13.0	Chocolate
11	2.9	20.8	7.5	Yellowish gray

P.C.E.: Cone 15

This shale is similar to Sample No. 38, but does not have quite as satisfactory a firing range, as volume shrinkage decreased slightly at cone 7, indicating the start of overfiring. It is suitable for the manufacture of vitrified products. It has a fair color when fired.

Sample 40. Shale

This sample was selected from near the crest of Shades Mountain on U. S. Highway 31 near Homewood. In places it appears to be black, but has a gray color when dry. The shale, about 15-20 feet thick to the bottom of the road cut, is overlain by 10 feet of yellow-weathered shale, which in turn is overlain by about 15-20 feet of hard sandstone to the top of the road cut. The shale is rather massive. It slakes into plates and conchoidal fragments. A chemical test showed considerable magnesia and lime.

Geological formation: Pottsville

Working properties: Very good

Drying behavior:

Linear drying shrinkage	3.4%
Volume drying shrinkage	9.8
Pore water	17.5
Shrinkage water	5.3
Water of plasticity	22.8
Drying defects	None

Transverse strength: 243 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	31.7	6.8	2.3	Buff
06	26.4	12.8	4.35	Salmon
04	19.9	19.05	6.8	Salmon
02	9.6	26.7	9.9	Light brownish red
1	5.6	27.85	10.3	Light brownish red
3	0.4	29.8	11.1	Deep brownish red
5	0.3	29.1	10.8	Deep brownish red
7	0.15	24.55	9.0	Deep brownish red

P.C.E.: Cone 14

This shale can probably be used for the manufacture of vitrified ware, although some care would be necessary as the vitrification range is rather short. It is rather difficult to oxidize and should be handled carefully during the water smoking period. The presence of lime and magnesia account for its rather short firing range. It has a very good color when fired.

Sample 47. Shale

The sample was taken from a road cut on the short-cut road between Bessemer and Acton, 0.3 mile west of U. S. Highway 31. The shale is light gray in color and is a fairly soft fissile shale which slakes in water.

Geological formation: Pottsville

Working properties: It should be mixed rather dry, but worked satisfactorily through the auger machine.

Drying behavior:

Linear drying shrinkage	4.7%
Volume drying shrinkage	13.5
Pore water	19.0
Shrinkage water	7.7
Water of plasticity	26.7
Drying defects	None noted

Transverse strength: 252 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	34.9	4.35	1.5	Buff
06	28.2	10.85	3.8	Buff
04	20.05	21.0	7.6	Light brownish red
02	10.3	28.55	10.6	Brownish red
1	5.2	31.1	11.7	Brownish red
3	0.4	32.0	12.1	Deep brownish red
5	0.3	31.4	11.9	Deep brownish red
7	0.0	29.6	11.1	Deep brownish red
9	10.8	19.6	7.1	Chocolate

P.C.E.: Cone 14

This shale should work satisfactorily for most ceramic products, as it has a satisfactory firing range. The shale had a very good color when fired.

Sample 48. Shale

This appears to be the same shale as Sample No. 47, but the sample was taken 2.3 miles west of U. S. Highway No. 31 on the short cut between Bessemer and Acton. There is an exposure of 20 feet below a sandstone. The shale is fairly soft and has a brownish color. It slaked slightly, but is coarse-grained.

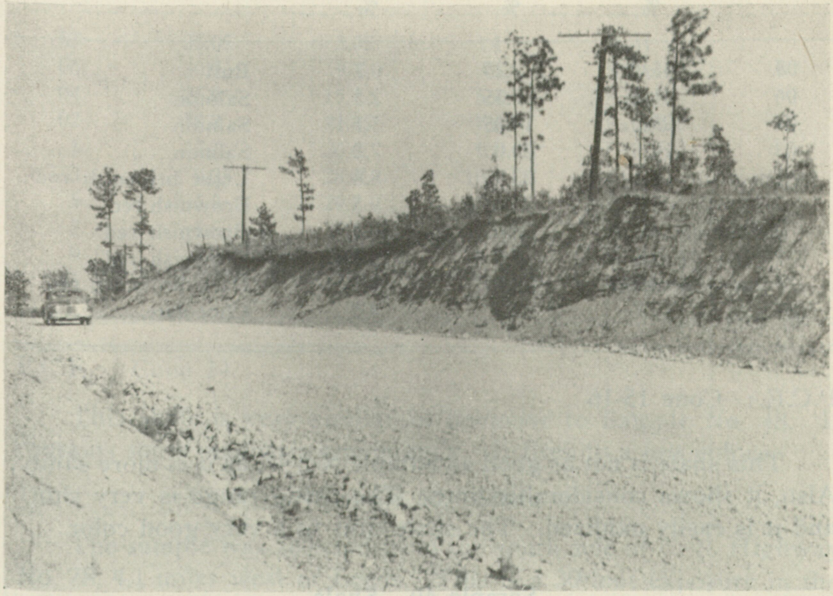


Fig. 8.—Pottsville shale on short-cut road between Acton and Bessemer 2.3 miles west of U. S. Highway 31, Jefferson County. Sample No. 48.

Geological formation: Pottsville

Working properties: Fair; it is a little sandy

Drying behavior:

Linear drying shrinkage	2.3%
Volume drying shrinkage	6.6
Pore water	17.9
Shrinkage water	3.9
Water of plasticity	21.8
Drying defects	None noted

Transverse strength: 190 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	35.05	2.25	0.7	Buff
06	31.25	7.35	2.5	Salmon
04	25.2	14.35	5.1	Salmon
02	19.1	20.0	7.2	Salmon
1	14.3	23.9	8.8	Light brownish red
3	11.0	25.8	9.5	Brownish red
5	8.5	28.0	10.4	Brownish red
7	1.8	27.9	10.4	Brownish red
9	2.2	22.8	8.3	Dark brownish red
11	19.7	12.8	4.5	Chocolate

P.C.E.: Cone 15-16

This shale is not as good as Sample No. 47, as it is more sandy. Also, it shows considerable lime. The firing range is very short, and it is easily oxidized. The shale fires to a very good color.

Sample 49. Shale

This sample came from the same strata as sample No. 48. It was obtained 0.1 mile west of Sample 48, and 20 to 30 feet lower topographically. The thickness of the shale exposed at localities 48 and 49 must amount to 70 feet or more. It has a fissile structure, and is fairly soft. It is light greenish-brown in color and slakes slightly.

Geological formation: Pottsville

Drying behavior:

Linear drying shrinkage	3.4%
Volume drying shrinkage	9.8
Pore water	18.7
Shrinkage water	5.5
Water of plasticity	24.2
Drying defects	None noted

Transverse strength: 163 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	35.05	3.05	1.1	Buff
06	30.0	9.7	3.4	Salmon
04	25.0	15.1	5.4	Salmon
02	18.8	21.05	7.6	Salmon
1	12.7	26.0	9.6	Salmon
3	9.25	28.0	10.4	Light brownish red
5	5.9	29.7	11.1	Brownish red
7	1.6	29.4	11.0	Brownish red
9	3.8	22.5	8.2	Brownish red
11	17.2	14.9	5.2	Yellowish gray

P.C.E.: Cone 14

This shale is very similar in behavior to Sample No. 48. It contains some magnesia compounds. It fires to a fair color.

Sample 50. Shale

The sample was selected from the south side of U. S. Highway No. 78, 4.1 miles west of Leeds. This is a 30-foot exposure in the north part of the Cahaba coal field. This was a very hard shale with a light yellow-brown color.

Geological formation: Pottsville

Working properties: It could not be wedged, and would not extrude through the machine.

P.C.E.: Cone 13-14

LAWRENCE COUNTY

Sample 12. Shale

The sample was collected from a road cut on the east side of the highway through the Bankhead National Forest 14 miles south of Moulton, 8.9 miles south of the north boundary of the forest, and 1.1 miles north of the Lawrence County line. This is a sandy fissile shale, yellow in color due to weathering, and slaked only slightly.

Geological formation: Pottsville

Working properties: It is rather sandy, but could be extruded satisfactorily through the auger machine.

Drying behavior:

Linear drying shrinkage	2.7%
Volume drying shrinkage	7.9
Pore water	20.1
Shrinkage water	5.2
Water of plasticity	25.3
Drying defects	None noted

Transverse strength: 167 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	40.95	1.5	0.6	Light salmon
06	40.0	3.75	1.3	Light salmon
04	38.1	5.65	2.0	Salmon
02	33.9	10.35	3.6	Brownish red
1	32.2	12.0	4.2	Brownish red
3	30.0	16.1	5.7	Reddish brown
5	29.4	16.3	5.8	Reddish brown
7	24.0	20.9	7.6	Reddish brown
9	14.9	27.9	10.3	Deep brownish red
11	16.3	24.2	8.8	Gun metal

P.C.E.: Cone 14

The shale is rather sandy and has a high pore with low shrinkage water content. It overfires at cone 11, and never reaches a low porosity. Also, it contains some calcium and magnesium compounds. It would be valuable only for the manufacture of common building brick. The color after firing is not pleasing.

Sample 13. Shale

The shale bed is about 10 feet thick, and lies between limestone beds about half way up the limestone escarpment on State Highway 36 to Moulton, 3.2 miles south of the junction with State Highway 20. This can be classed as a very hard sandy shale. It is variegated gray to white in color, and slakes only slightly in water.

Geological formation: Gasper

Working properties: The shale did not work satisfactorily as it was too sandy and came out of the machine rather soft.

Drying behavior:

Linear drying shrinkage	4.0%
Volume drying shrinkage	11.5
Pore water	16.9
Shrinkage water	6.3
Water of plasticity	23.2
Drying defects	None noted

Transverse strength: 278 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	33.95	0.3	0.1	Light buff through tans to very light gray at cone 9.
06	33.9	0.65	0.2	
04	34.0	1.0	0.3	
02	34.0	0.6	0.2	
1	33.0	1.7	0.6	

3	31.8	2.0	0.7	
5	32.0	2.3	0.8	
7	31.0	3.6	1.2	
9	28.7	5.7	2.0	
11	26.5	8.5	3.0	Grayish tan
13	23.7	9.6	3.4	Grayish tan

P.C.E.: Cone 26

The properties are those of a very sandy shale or clay. In order to obtain a lower porosity it would be necessary to fire to a much higher temperature. Considering the high silica content, it has a very good dry transverse strength. It is unlikely that this material would have any commercial value, except as a clay to be used for daubing, or it might be used in molding sands.

MARENGO COUNTY

Sample 71. Shale or bedded clay

The deposit is located on U. S. Highway No. 43, 8.3 miles south of Linden Court House. It is a soft shale or bedded clay of a dark yellow-brown color. It slakes as plates which can be readily rubbed to form a mud. Chemical tests indicate a comparatively large gypsum content. It consists primarily of illite and quartz.

Geological formation: Oak Hill beds of the Naheola formation

Working properties: It works well through the machine, but does not appear to be very plastic

Drying behavior:

Linear drying shrinkage	11.9%
Volume drying shrinkage	31.5
Pore water	25.2
Shrinkage water	19.4
Water of plasticity	44.6
Drying defects	High shrinkage, must be dried with care

Transverse strength: 708 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	42.0	6.1	2.1	Buff
06	38.85	12.15	4.3	Buff
04	36.6	17.6	6.3	Salmon
02	21.9	27.2	10.1	Dark salmon
1	15.25	31.8	12.0	Reddish brown
3	11.3	33.0	12.5	Reddish brown
5	18.5	24.5	9.0	Reddish brown

P.C.E.: Cone 14

The shale bloated at cone 5, and never reached a low porosity. If used alone, it is of no value for the manufacture of ceramic products. The color after firing is poor.

Sample 72. Shale or bedded clay

The material was taken from a road cut on U. S. Highway No 43, 2.4 miles south of Dixons Mill. When dry it is yellowish-brown in color and slakes readily to a mud. It consists essentially of illite and quartz.

Geological formation: Upper part of Nanafalia formation, Wilcox group

Working properties: It worked satisfactorily

Drying behavior:

Linear drying shrinkage	14.5%
Volume drying shrinkage	37.3
Pore water	26.2
Shrinkage water	24.1
Water of plasticity	50.3
Drying defects	It must be dried with great care on account of high shrinkage

Transverse strength: 630 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	41.0	5.85	2.1	Buff
06	39.1	9.3	3.2	Buff
04	36.8	14.7	5.2	Salmon
02	30.3	22.5	8.2	Light brownish red
1	28.5	24.0	8.8	Light brownish red
3	26.3	26.1	9.6	Light brownish red
5	25.75	28.4	10.6	Light brownish red
7	23.5	25.9	9.6	Light brownish red
9	11.75	34.6	13.2	Deep brownish red
11	9.7	36.2	14.0	Very deep brownish red

P.C.E.: Cone 14

The clay has a high dry strength and a favorable porosity and shrinkage curve as it does not tend to readily overfire. It is an open firing clay, and might be used as a bond clay, although it does not appear to be plastic when first mixed with water. The color after firing is good.

Sample 73. Shale or bedded clay

The sample was taken from a road cut 3.1 miles south of Dixons Mill on U. S. Highway No. 43. It is soft, is gray in color, and slakes to a mud. It consists primarily of illite and quartz.

Geological formation: Tuscahoma

Working properties: It does not mix well with water, and does not appear to be very plastic. However, it could be extruded satisfactorily.

Drying behavior:

Linear drying shrinkage	8.4%
Volume drying shrinkage	23.1
Pore water	24.7
Shrinkage water	14.2
Water of plasticity	38.9
Drying defects	None noted

Transverse strength: 371 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	42.3	2.45	0.9	Buff
06	38.5	9.4	3.3	Salmon
04	33.65	15.9	5.6	Salmon
02	23.2	26.9	10.0	Dark salmon
1	17.2	31.5	11.9	Brownish red
3	14.6	31.4	11.9	Reddish brown
5	20.0	27.0	10.0	Reddish brown

P.C.E.: Cone 11-12

At cone 5 one bar bloated and the other appeared to be satisfactory. The material has a very short firing range. It might be used for light-weight concrete aggregate, but would not be satisfactory for making ceramic products. The color after firing is poor.

MARION COUNTY

Sample 17. Shale

The sample was selected from a road cut on U. S. Highway No. 43, 18 miles north of Hamilton, on the west side of the road north of the creek, 6 miles south of Phil Campbell. This lies in the upper part of the Pottsville formation above the massive sandstone exposed in the bank of the creek. It lies below the Tuscaloosa gravel which is exposed in other cuts near this locality. It it a soft fissile shale, gray in color and slakes readily.

Geological formation: Pottsville

Working properties: Good

Drying behavior:

Linear drying shrinkage	6.8%
Volume drying shrinkage	19.0
Pore water	17.5
Shrinkage water	10.0
Water of plasticity	27.5
Drying defects	None noted

Transverse strength: 327 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	33.8	7.25	2.5	Reddish cream
06	30.35	11.7	4.1	Salmon
04	25.4	17.2	6.1	Salmon
02	16.45	25.4	9.4	Brownish red
1	12.4	27.7	10.3	Brownish red
3	0.3	30.3	11.4	Brownish red
5	0.15	31.2	11.7	Deep brownish red
7	0.0	30.8	11.5	Deep blackish red
9	14.7	18.4	6.6	Dark gun metal
11	18.1	10.6	3.7	Dark gray

P.C.E.: Cone 13

This shale reaches zero porosity at cone 7 and has a fairly long firing range except that there is a rapid drop in porosity between cone 1 and 3. However, there is not a great volume change between these two cone temperatures. This shale would be satisfactory for the manufacture of vitrified structural clay products.

However, it does not oxidize readily. It has a good color when fired.

Sample 93. Shale

The sample was taken from a road cut on State Highway No. 5 between Phil Campbell and Haleyville, and 4.2 miles northwest of Haleyville. The distance was measured from a big building with pillars in downtown Haleyville. It is a fairly soft carbonaceous shale, gray in color, which slakes readily in water.

Geological formation: Lower Pottsville

Working properties: It is plastic and works well.

Drying behavior:

Linear drying shrinkage	3.9%
Volume drying shrinkage	11.2
Pore water	16.5
Shrinkage water	6.0
Water of plasticity	22.5
Drying defects	None noted

Transverse strength: 242 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	34.25	2.5	0.8	Buff
06	32.4	5.55	1.9	Buff
02	24.8	14.3	5.0	Dark salmon
1	23.5	15.55	5.5	Dark salmon
3	20.2	18.5	6.6	Brownish red
5	17.8	20.3	7.3	Brownish red
7	12.7	24.0	8.7	Reddish brown
9	7.7	25.5	9.3	Chocolate
11	8.5	19.9	7.1	Gun metal

P.C.E.: Cone 14-15

This is a fairly good shale, but would not be very satisfactory for vitrified ware as it never reaches low porosity. The dry strength is sufficiently high. Some care would be needed during the oxidation period on account of a rather high carbon content. The color of the fired bars is fair.

ST. CLAIR COUNTY

Sample 51. Shale

The sample was selected from an 8-10 foot exposure of shale 4.2 miles east of Leeds and 0.8 mile west of the railroad station at Brompton on U. S. Highway No. 78. It is dark where unweathered, and light yellow-brown on the weathered surfaces. The shale is very sandy and did not slake.

Geological formation: Floyd

Working properties: It could not be extruded as it was too sandy.

P.C.E.: Cone 20

Sample 52. Shale

The sample was taken from a 40-foot exposure of gray shale beneath thick sandstone, 0.8 mile east of Brompton on U. S. Highway No. 78 at the bridge over Kelly Creek. It has a brownish gray color, is hard, but slakes when put in water.

Geological formation: Parkwood

Working properties: Very good

Drying behavior:

Linear drying shrinkage	4.3%
Volume drying shrinkage	12.3
Pore water	18.0
Shrinkage water	6.5
Water of plasticity	24.5
Drying defects	None noted

Transverse strength: 264 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	34.4	5.25	1.8	Buff
06	29.9	10.55	3.7	Salmon
04	22.8	17.8	6.3	Salmon
02	17.1	22.8	8.3	Light brownish red
1	12.0	26.7	9.8	Light brownish red
3	7.95	28.9	10.8	Light brownish red
5	6.7	29.4	11.0	Brownish red
7	0.3	29.7	11.1	Brownish red
9	0.3	28.45	10.6	Brownish red
11	10.5	17.3	6.1	Chocolate

P.C.E.: Cone 14

The shale has a short vitrification range, but it could probably be used for most structural clay products. It oxidizes fairly readily. Mining would be difficult from the deposit from which the sample was taken. Undoubtedly there are accessible deposits in the same formation. It has a very good color when fired.

Sample 53. Shale

The sample was taken from a 40-50 foot exposure of black shale beneath a thick bed of sandstone 1.1 miles east of Brompton on U. S. Highway No. 78 and 0.3 mile east of sample No. 52. This is a hard carbonaceous shale with a conchoidal fracture. It slaked into conchoidal fragments. It is gray in color when dry.

Geological formation: Lower Pottsville

Working properties: Very good

Drying behavior:

Linear drying shrinkage	5.6%
Volume drying shrinkage	15.9
Pore water	14.8
Shrinkage water	8.1
Water of plasticity	22.9
Drying defects	None noted

Transverse strength: 366 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	32.3	6.35	2.2	Buff
06	28.3	11.5	4.0	Salmon
04	18.9	21.2	7.7	Salmon
02	11.4	26.7	9.9	Brownish red
1	9.7	27.6	10.3	Brownish red
3	0.6	29.6	11.1	Dark brownish red
5	0.3	30.0	11.3	Dark brownish red
7	0.15	29.9	11.2	Very dark brownish red
9	3.1	22.3	8.1	Very dark brownish red
11	8.7	12.8	4.5	Chocolate

P.C.E.: Cone 14

This is a very good shale. It has high dry strength and a good vitrification range, and would be suitable for the manufacture of most structural clay products. Some care would be needed during firing to insure complete oxidation. It has a good color when fired.

Sample 54. Shale

The sample was obtained 2.4 miles east of Brompton on Highway 78 and about 1 3 miles east of Sample No. 53. There was about 30 feet or more exposed, and this was overlain with sandstone. This is a different shale from Sample No. 53. The shale is very hard and has a greenish-black color.

Geological formation: Pottsville

Working properties: It could not be extruded

P.C.E.: Cone 10-11

In so far as we know this material cannot be used for the manufacture of the usual ceramic products. Because it has a low fusion point and tends to bloat readily, it might be satisfactory for making a light-weight concrete aggregate.

Sample 55. Shale

The sample was taken from a 10-12 foot exposure of shale, 4.0 miles north of Pell City on State Highway No. 25. This is a platy black shale which is very hard and does not slake in water.

Geological formation: Floyd shale

Working properties: It might be possible to extrude if it were ground finer. However, it could not be extruded when ground to minus 20 mesh and mixed with water. Non-plastic.

P.C.E.: Cone 15-16

Sample 56. Shale

The sample was collected at the pit of the Alphons Custodis Company ½ mile southeast of Ragland on the railroad. There is an exposure of 100-130 feet of uniformly horizontally bedded shale making up the face of the hill 100 yards south of the plant. This is a hard carbonaceous dark gray shale which does not slake readily in water.

The chemical analysis of the shale is as follows:

Ignition loss	8.06%
SiO_2	55.36
Al_2O_3	20.10

Fe_2O_3	8.05
TiO_2	0.81
CaO	0.52
MgO	2.12
Alkalies as Na_2O	3.27
	98.29

Geological formation: Pottsville

Working properties: It is not very plastic, but can be satisfactorily extruded.

Drying behavior:

Linear drying shrinkage	3.2%
Volume drying shrinkage	9.2
Pore water	12.7
Shrinkage water	4.5
Water of plasticity	17.2
Drying defects	None noted

Transverse strength: 204 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	27.8	4.7	1.6	Salmon
06	25.7	7.1	2.5	Salmon
04	19.4	13.7	4.8	Salmon
02	12.6	19.2	6.9	Light brownish red
1	10.25	21.7	7.9	Light brownish red
3	7.3	22.2	8.1	Dark brownish red
5	5.7	22.55	8.2	Dark brownish red
7	4.7	20.8	7.5	Chocolate
9	11.0	13.4	4.7	Chocolate

P.C.E.: Cone 12-13

This scale has been used with satisfactory results for the manufacture of brick, acid rings and other ceramic products. It needs

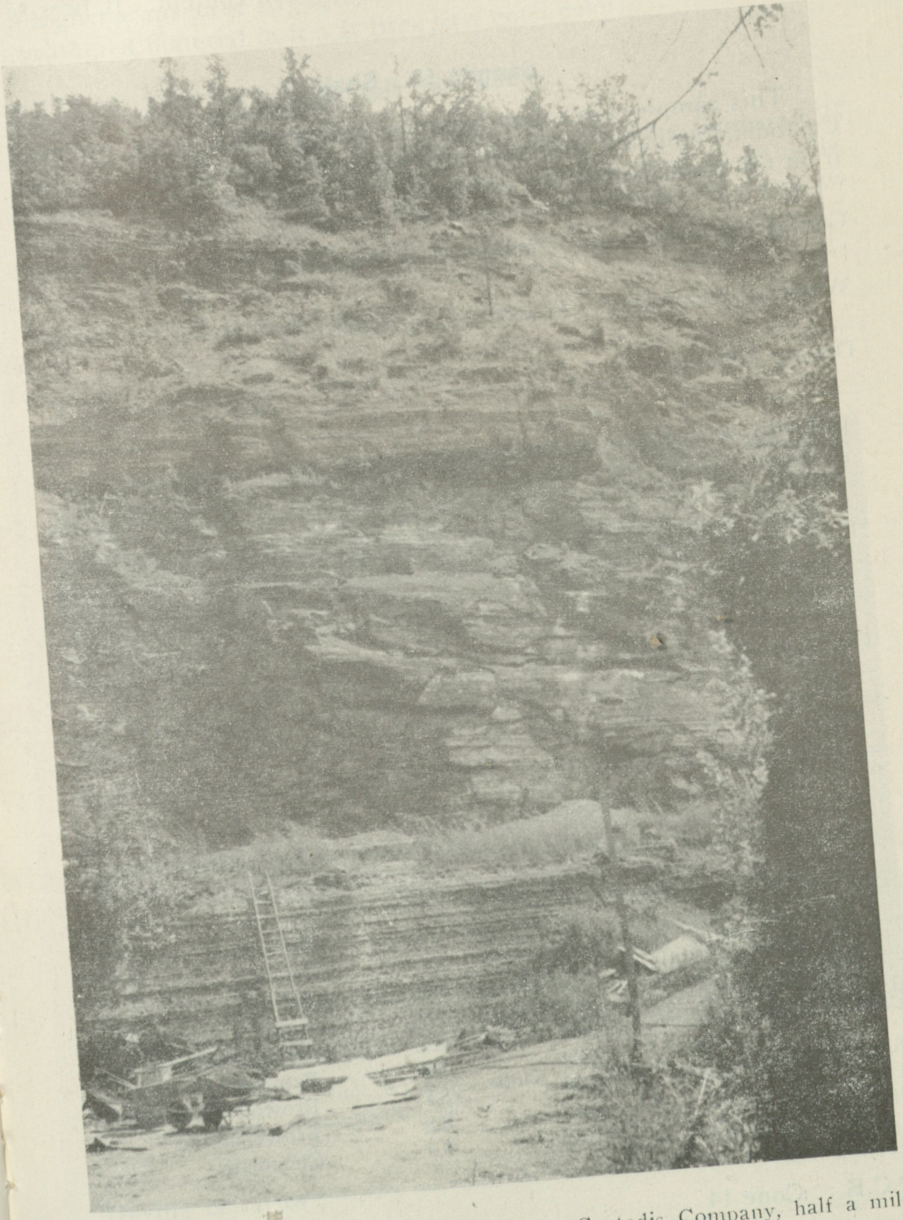


Fig. 9.—Pottsville shale pit of Alphons Custodis Company, half a mile east of Ragland, St. Clair County. Sample No. 56.

some care in oxidation as it has a high carbon content. It fires to a good color.

Sample 57. Shale

This sample was taken from the storage bins of the Alphons Custodis Company, Ragland, and contains some weathered shale from the upper half of the exposure.

Geological formation: Parkwood or Pottsville

Working properties: It worked satisfactorily

Drying behavior:

Linear drying shrinkage	3.1%
Volume drying shrinkage	9.0
Pore water	14.4
Shrinkage water	4.6
Water of plasticity	19.0
Drying defects	None noted

Transverse strength: 269 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	30.7	3.6	1.2	Salmon
06	26.6	8.35	2.9	Salmon
04	21.1	13.7	4.8	Salmon
02	14.0	20.4	7.4	Light brownish red
1	10.0	23.2	8.5	Light brownish red
3	6.95	24.4	9.0	Brownish red
5	4.8	23.8	8.7	Brownish red
7	3.1	24.1	8.8	Brownish red
9	11.6	15.4	5.4	Chocolate

P.C.E.: Cone 14

The firing characteristics are very similar to that of Sample No. 56. The shale has slightly better working properties and has a higher transverse strength. The shale oxidized faster due to the weathered material in it. It fires to a good color.

Sample 58. Shale

The sample was taken from a road cut on State Highway 25 about 14 miles north of Pell City and 6.1 miles south of Ashville. There is a 25-foot exposure. This is a soft weathered shale yellow-brown in color. It slakes readily.

Geological formation: Floyd

Working properties: Very good

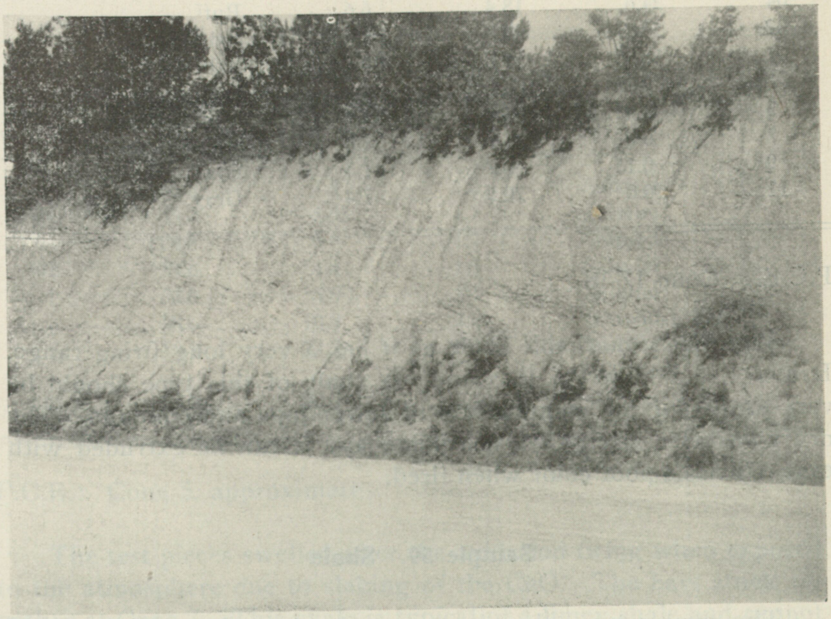


Fig. 10.—Floyd shale 6.1 miles south of Ashville on State Highway 25, St. Clair County. Sample No. 58.

Drying behavior:

Linear drying shrinkage	6.1%
Volume drying shrinkage	17.2
Pore water	19.0

Shrinkage water	9.6
Water of plasticity	28.6
Drying defects	None noted

Transverse strength: 363 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	35.2	5.25	1.8	Buff
06	27.8	12.7	4.5	Buff
04	24.6	18.4	6.6	Buff
02	12.8	24.4	9.0	Salmon
1	12.05	27.6	10.3	Salmon
3	2.75	30.0	11.3	Redlish brown
5	0.45	30.6	11.5	Reddish brown
7	0.0	31.6	11.9	Reddish brown
9	0.15	30.2	11.3	Gray
11	10.0	20.5	7.4	Gray

P.C.E.: Cone 17-18

This is a remarkable shale as it has a very long firing range. It also has a high P.C.E. value. A shale of this type should be very useful for the manufacture of sewer pipe and conduits. The dry transverse strength is excellent, and it can be extruded with ease. It has a poor color when fired.

Sample 59. Shale

The sample was taken from a road cut on State Highway 25 about 17 miles north of Pell City, 3 miles south of Ashville, and 3 miles north of Sample 58. The thickness of the bed must be more than 400 feet as the length of the exposure is about 600 feet and the dip is about 45°. The height of the exposure is 15 feet. This is a weathered calcareous greenish-yellow shale. It slakes readily in small pieces.

Geological formation: Conasauga

Working properties: Fair

Drying behavior:

Linear drying shrinkage	5.4%
Volume drying shrinkage	15.2
Pore water	12.7
Shrinkage water	7.7
Water of plasticity	20.4
Drying defects	None noted

Transverse strength: 378 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	36.2	4.5	1.6	Salmon
06	35.4	5.05	1.7	Salmon
04	34.8	5.0	1.7	Salmon
02	34.6	4.4	1.5	Salmon
1	32.8	6.0	2.1	Salmon
3	28.6	10.9	3.8	Brownish red
5	10.1	22.3	8.1	Reddish brown, speckled
7	5.8	22.2	8.1	Gun metal

P.C.E.: Cone 5, approximate

The test pieces swelled after the oxidation firing when exposed to the atmosphere due to slaking of the CaO. The bars stuck together at Cone 7. This shale is typical of a limey shale and cannot be successfully used for high grade products. Poor color.

SHELBY COUNTY

Sample 34. Shale

The sample was collected from a road cut on State Highway No. 25 between Calera and Montevallo, 4 miles east of Montevallo and 2.8 miles west of Calera railroad station. The outcrop is on the south side of the road in a bluff 20 feet high. It is a uniform shale in a bed 15 feet thick to the bottom of the road cut, overlain by sandstone 1-2 feet thick. It is weathered a yellowish brown color on the surfaces of the plates, and is a hard fissile which slaked only slightly.

Geological formation: Floyd shale

Working properties: It appeared to be sandy when mixed with water, but could be satisfactorily extruded.

Drying behavior:

Linear drying shrinkage	3.6%
Volume drying shrinkage	10.2
Pore water	17.9
Shrinkage water	5.7
Water of plasticity	23.6
Drying defects	None noted

Transverse strength: 182 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	31.8	5.3	1.8	Buff
06	27.6	9.1	3.1	Reddish buff
04	19.75	15.3	5.4	Salmon
02	11.4	21.85	8.0	Brownish red
1	11.0	22.35	8.1	Brownish red
3	7.6	24.1	8.8	Brownish red
5	6.85	23.5	8.6	Very deep brownish red

P.C.E.: Cone 14

The shale started to overfire at cone 5 and is not satisfactory for the manufacture of most structural clay products. It might be satisfactory for a light-weight aggregate. The colors of the fired test pieces are excellent.

Sample 35. Shale

This deposit is located a short distance east of Shelby Springs on State Highway No. 25 to Columbiana, 5.7 miles east of the Calera railroad station. The dip is east or southeast at about 70 to 80 degrees. It is varegiated in color from reddish-yellow to gray and white and was fissile and moderately hard. It did not slake in water.

Geological formation: Waxahatchee slate of the Talladega series

Working properties: It appeared to be sandy when mixed with water, but worked satisfactorily through the machine.

Drying behavior:

Linear drying shrinkage	3.1%
Volume drying shrinkage	9.0
Pore water	20.2
Shrinkage water	5.3
Water of plasticity	25.5
Drying defects	None noted

Transverse strength: 126 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	40.5	0.0	0.0	Light buff
06	35.45	7.9	2.7	Light buff
04	29.6	14.9	5.2	Salmon
02	24.5	19.95	7.2	Light brownish red
1	22.5	21.7	7.9	Brownish red
3	16.3	27.05	10.0	Brownish red
5	15.1	27.4	10.1	Brownish red
7	12.6	28.9	10.8	Dark brownish red
9	9.9	29.7	11.1	Chocolate
11	9.1	29.5	11.0	Chocolate
13	16.3	19.8	7.1	Yellowish gray

P.C.E.: Cone 16

This material has a low dry strength and would be difficult to handle in the dry condition. It never reaches a low porosity and would probably be valuable only for common brick. It overfires at cone 13, which is fairly high. The shale has a satisfactory color when fired.

Sample 36. Shale

This is a variegated colored shale located on State Highway No. 25 in the city limits of Columbiana about a quarter of a mile west of town on the north side of the road. The dip is about 60 to 70 degrees south or southeast. It contains gray, red and white pieces and is fairly soft, although it contains hard pieces. It did not slake in water.

Geological formation: Waxahatchee slate of the Talladega series

Working properties: It was not very plastic, but could be extruded satisfactorily.

Drying behavior:

Linear drying shrinkage	5.1%
Volume drying shrinkage	14.6
Pore water	24.6
Shrinkage water	8.1
Water of plasticity	32.7
Drying defects	None noted

Transverse strength: 208 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	41.9	3.95	1.3	Buff
06	37.1	12.1	4.2	Buff
04	31.5	18.5	6.6	Buff

02	27.0	23.1	8.4	Salmon
1	22.8	27.0	10.0	Salmon
3	17.25	30.6	11.5	Light brownish red
5	16.25	31.5	11.8	Light brownish red
7	12.4	32.9	12.5	Reddish brown
9	10.5	33.55	12.7	Reddish brown
11	7.2	34.0	13.0	Chocolate
13	15.5	23.9	8.7	Yellowish brown

P.C.E.: Cone 17

The material has a fairly high fusion point. There would be no difficulty in the shale overfiring, but it would not be satisfactory for vitrified products. It has a satisfactory color when fired.

Sample 37. Shale

The deposit from which the sample was taken is on U. S. Highway No. 31 in a road cut on the west side of the road opposite a coal mine near Acton, about 2 miles north of Acton and about one-half mile south of the Cahaba River. It is a fissile shale, gray-blue in color, and did not slake when placed in water.

Geological formation: Pottsville

Working properties: It is not very plastic, but could be extruded from the machine satisfactorily.

Drying behavior:

Linear drying shrinkage	2.3%
Volume drying shrinkage	6.7
Pore water	17.6
Shrinkage water	3.6
Water of plasticity	21.2
Drying defects	None noted

Transverse strength: 270 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	33.9	3.0	0.1	Buff
06	29.75	8.8	3.1	Salmon
04	24.0	14.5	5.1	Salmon
02	16.9	20.9	7.6	Light brownish red
1	10.9	25.65	9.2	Light brownish red
3	1.7	29.0	10.8	Dark reddish brown
5	0.3	29.0	10.8	Dark reddish brown
7	1.9	15.5	6.5	Chocolate

P.C.E.: Cone 14

This shale tends to bloat at cone 7 and has a very short firing range. It would not be satisfactory for structural clay products other than brick, however, it might be used for making a lightweight concrete aggregate. The shale has a good color when fired.

Sample 38. Shale

The sample was taken from a deposit on U. S. Highway No. 31 about 0.2 mile north of Sample No. 37 on the east side of the road at a small gasoline station. It is a yellow weathered shale about 5 feet thick, extending to the top of the road cut, and is underlain by a soft green sandstone. The shale is soft and slakes readily into small plates.

The chemical analysis of the shale is as follows:

Ignition loss	7.08%
SiO_2	58.39
Al_2O_3	21.64
Fe_2O_3	6.30
TiO_2	0.84
CaO	0.52
MgO	2.12
Alkalies as Na_2O	3.62
	99.08

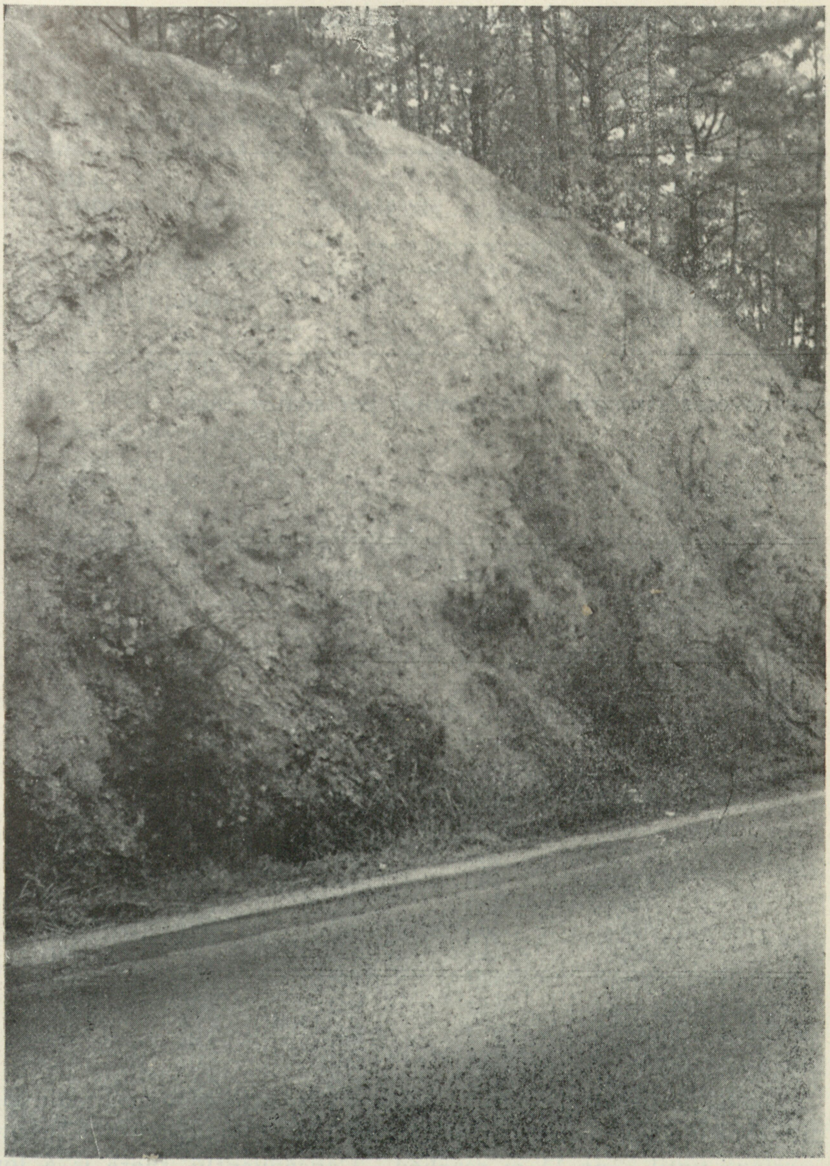


Fig. 11.—Pottsville shale about 2 miles north of Acton and half a mile south of the Cahaba River on U. S. Highway 31, Shelby County. Sample No. 37.

Geological formation: Pottsville

Working properties: It is very satisfactory

Drying behavior:

Linear drying shrinkage	4.4%
Volume drying shrinkage	12.2
Pore water	25.7
Shrinkage water	7.7
Water of plasticity	33.4
Drying defects	None noted

Transverse strength: 175 pounds per sqaure inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	42.4	3.05	1.1	Light buff
06	38.0	10.15	3.5	Buff
04	30.65	19.25	6.9	Buff
02	17.7	31.2	11.8	Salmon
1	14.0	33.5	12.7	Salmon
3	0.3	39.15	15.3	Brownish red
5	0.3	39.2	15.3	Dark brownish red
7	0.0	39.1	15.3	Dark brownish red
9	0.15	36.1	13.9	Chocolate
11	5.5	27.1	10.0	Gun metal

P.C.E.: Cone 16

This shale reaches minimum porosity at cone 3 and maintains it to cone 11. Overfiring starts at cone 9, but does not become serious until cone 11 is reached. Consequently, there is a long firing range and the shale is valuable for the manufacture of vitrified clay products. The transverse strength is a little low, consequently some care would be necessary in handling green ware. The P.C.E. is high for a shale. It has a fair color when fired.

Sample 42. Clay

The sample was taken from the shallow pit of the Montevallo Brick and Tile Company. The plant is located about 2 miles northwest of Montevallo. There is from 5 to 8 feet of a weathered clay-like material overlying a blue-gray dolomite. The clay is red colored, weathered, and slakes readily when placed in water.

Geological formation: Conasauga

Working properties: It works satisfactorily, but if anything it is slightly too plastic.

Drying behavior:

Linear drying shrinkage	18.6%
Volume drying shrinkage	46.0
Pore water	24.8
Shrinkage water	21.2
Water of plasticity	46.0
Drying defects	None noted

Transverse strength: 343 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	30.4	21.7	7.8	Light salmon
06	18.6	32.5	12.2	Salmon
04	6.1	38.4	15.0	Brownish red
02	0.7	39.8	15.6	Brownish red
1	0.2	38.3	14.9	Reddish brown
3	0.5	32.0	12.1	Reddish brown
5	0.3	27.7	10.2	Reddish brown

P.C.E.: Cone 15-16

This material has a fairly high fusion point if we consider its firing characteristics as there are signs of overfiring at as low as cone 1. This becomes serious at cone 3. The shale vitrifies at a very low temperature. It is also characterized by a very high firing and drying shrinkage. The fired color is a rich red. It may be possible to develop other uses for the shale as in the manufacture of red pottery and tile. The dry strength is good. The clay has an excellent color when fired.

Sample 43. Clay

This is the same as sample No. 42, but from another part of the pit. It is similar in character to sample No. 42.

Geological formation: Conasauga

Working properties. It worked very well

Drying behavior:

Linear drying shrinkage	14.1%
Volume drying shrinkage	36.7
Pore water	23.1
Shrinkage water	21.2
Water of plasticity	44.3
Drying defects	None noted

Transverse strength: 442 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	29.1	19.8	7.1	Salmon
06	22.5	26.1	9.6	Salmon
04	12.6	33.6	12.8	Salmon
02	4.9	38.4	14.9	Reddish brown
1	0.0	38.6	15.0	Reddish brown
3	0.0	33.4	12.7	Reddish brown
5	0.3	26.5	9.8	Reddish brown

P.C.E.: Cone 14

This clay is quite similar to Sample No. 42. It has a higher dry strength and less drying shrinkage, although the water of plasticity is about the same. It has a good color when fired.

Sample 44. Shale

The sample was taken from a ditch about one-half mile south of the Montevallo Brick Company and about 1.5 miles west of Montevallo. It is a hard greenish-yellow shale which slakes slightly in water.

Geological formation: Rome ("Montevallo")

Working properties: It was granular and did not work well through the auger machine.

Drying behavior:

Linear drying shrinkage	3.4%
Volume drying shrinkage	9.2
Pore water	14.8
Shrinkage water	8.4
Water of plasticity	23.2
Drying defects	None noted

Transverse strength: 174 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	32.25	2.8	1.0	Salmon
06	30.70	4.3	1.5	Salmon
04	27.3	8.5	2.9	Light brownish red
02	21.4	14.4	5.1	Brownish red
1	15.75	19.2	6.9	Brownish red
3	8.6	23.5	8.6	Brownish red
5	6.8	25.2	9.2	Brownish red

P.C.E.: Cone 10-11

The clay gave decided tests for both calcium and magnesium. The bars stuck together at cone 5 and consequently were not fired at cone 7. This shale would be of little value for ceramic products, but might be used for making a light-weight concrete aggregate. The colors of the fired bars are satisfactory, although the pieces tend to split.

Sample 45. Shale

The shale sample was selected from a road cut on the road from Maylene to Helena, 3.3 miles south of the Helena railroad station. It is a hard green metamorphosed shale which would not slake.

Geological formation: Rome ("Montevallo")

Working properties: It was non-plastic, and could not be used.

P.C.E.: Cone 9

The shale is of little value.

Sample 46. Shale

The sample was selected from the side of the road near the school house on the Maylene road in the town of Helena. It is a hard, partly metamorphosed shale, green in color. It slakes slightly.

Geological formation: Rome ("Montevallo")

Working properties: It appeared to be sandy, but ran through the machine satisfactorily.

Drying behavior:

Linear drying shrinkage	4.0%
Volume drying shrinkage	11.4
Pore water	13.7
Shrinkage water	6.1

Water of plasticity	19.8
Drying defects	None noted

Transverse strength: 262 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	21.35	8.6	3.0	Salmon
06	18.5	11.7	4.1	Salmon
04	12.75	17.6	6.3	Salmon
02	8.2	17.9	6.4	Light brownish red
1	6.5	13.8	4.8	Light brownish red
3	4.8	9.7	3.4	Light brownish red
5	0.3	—2.2	—0.8	Red

P.C.E.: Cone 13

The chemical tests show that the shale contains considerable amounts of both calcium and magnesium compounds. It bloats at cone 5 and shows signs of overfiring as low as cone 1. This is a very low temperature for overfiring. The shale would be of little value for the manufacture of ceramic products because it overfires so readily. However, it may find other uses such as in the production of light-weight concrete aggregates. The colors of the fired pieces are satisfactory.

Sample 76. Shale

The sample was taken from a road cut between Montevallo and Calera 2.5 miles west of Calera on State Highway No. 25, 35 feet exposed. This is a hard indurated shale which would not slake.

Geological formation: Floyd shale

Working properties: The shale is non-plastic and could not be worked.

P.C.E.: Cone 12-13

It is of no value for ceramic products, however, it might swell when heated and then be of use for a light-weight concrete aggregate.

Sample 77. Shale

The sample was selected from a road cut between Columbiana and Shelby, 3.3 miles south of Columbiana. There is an exposure of 200 feet of sandy weathered shale. It is mottled yellow to white in color, and slakes slightly in water.

Geological formation: Waxahatchee slate of the Talladega series

Working properties: It can be extruded satisfactorily, but it is sandy.

Drying behavior:

Linear drying shrinkage	4.3%
Volume drying shrinkage	12.3
Pore water	21.7
Shrinkage water	6.6
Water of plast'city	28.3
Drying defects	None noted

Transverse strength: 76 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	41.4	2.8	0.90	Buff
06	36.2	10.4	3.6	Reddish buff
04	31.0	17.1	6.1	Salmon
02	24.95	23.3	8.5	Light brownish red
1	20.3	27.1	10.0	Light brownish red
3	15.25	30.7	11.5	Medium brownish red
5	14.5	30.8	11.5	Medium brownish red
7	11.7	32.7	12.4	Dark brownish red
9	10.2	33.0	12.5	Dark brownish red
11	7.9	33.0	12.5	Chocolate

P.C.E.: Cone 16

The shale does not have high dry strength, but it can be worked satisfactorily. There is no danger in overfiring, but it would be impossible to obtain a vitrified product. The colors of the fired pieces are good.

Sample 78. Shale

The sample was taken from a road cut 4.5 miles west of Childersburg on State Highway No. 76, which is the short cut between State Highways Nos. 25 and 91. It is a metamorphosed shale with 50 feet exposed. It contains some quartz. The color is yellow, and it slaked only slightly.

Geological formation: Floyd

Working properties: It was not plastic enough to be extruded from the machine.

P.C.E.: Cone 10-11

This material is of no value for the manufacture of ceramic products.

TALLADEGA COUNTY

Sample 79. Phyllite

The sample was selected from a road cut 4.2 miles northwest of the city limits of Sylacauga on State Highway No. 91. The sample was red in color, and slaked in water.

Geological formation: Talladega

Working properties: The phyllite slaked to a non-plastic mass.

The water tended to squeeze out in the auger machine and it could not be worked.

P.C.E.: Cone 16-17

This material is not believed to be of value.

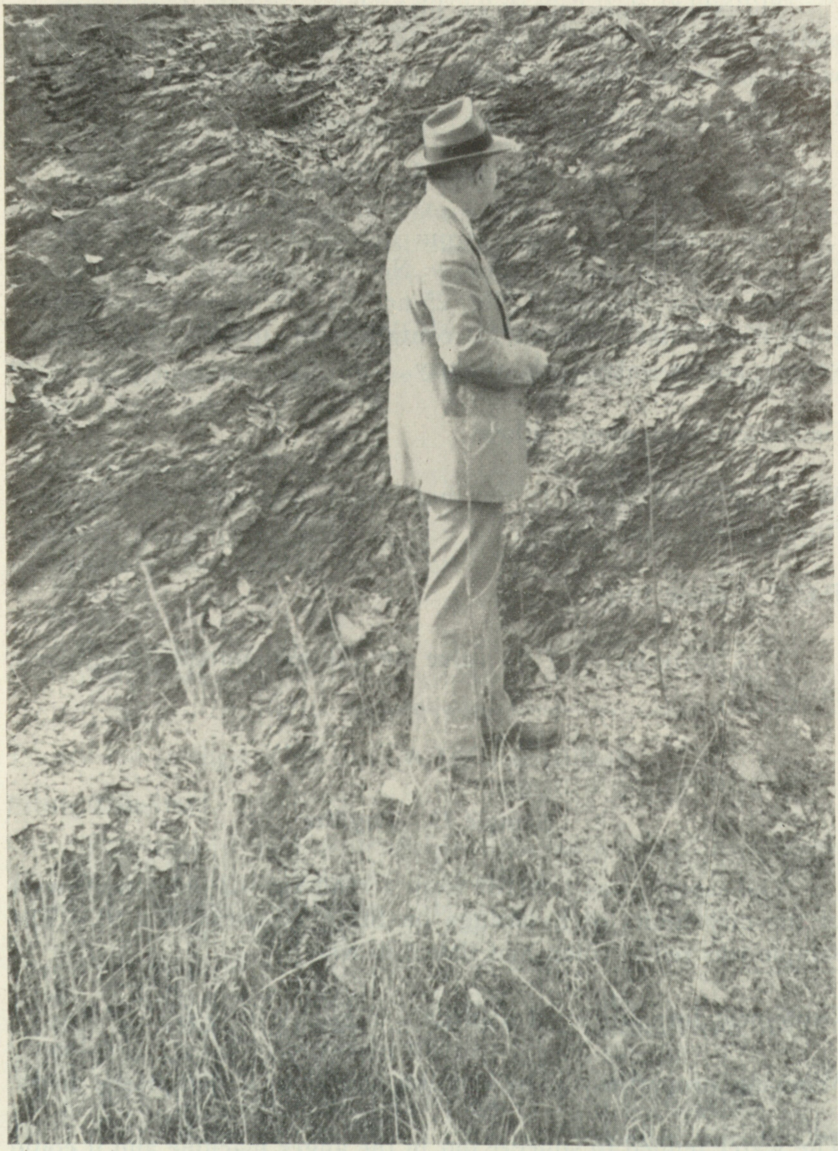


Fig. 12.—Talladega phyllite 3.5 miles north of Sylacauga on U. S. Highway 241, Talladega County. Sample No. 80.

Sample 80. Phyllite

The sample was collected 3.5 miles north of Sylacauga along U. S. Highway No. 241. There is an exposure of about 50 feet. The material is black in color, and would slake only slightly in water.

Geological formation: Talladega

Working properties: The phyllite was non-plastic, and could not be extruded from the auger machine.

P.C.E.: Cone 12-13

The material is probably of no value.

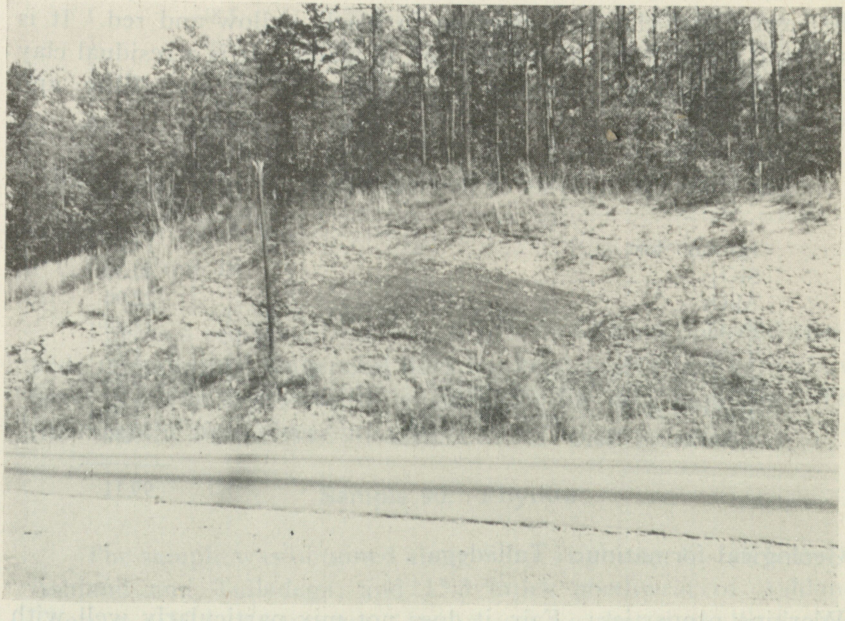


Fig. 13.—Talladega phyllite or slate 10.7 miles north of Sylacauga on U. S. Highway 241, Talladega County. Sample No. 81.

Sample 81. Phyllite

The sample was collected 10.7 miles north of Sylacauga on U. S. Highway No. 241. It is a fine-grained phyllite underlain by a white limestone. There is an exposure of 18 feet. It is black in color, very hard, and slakes as plates.

Geological formation: Talladega

Working properties: The phyllite was non-plastic, and could not be extruded.

P.C.E.: Cone 9

This material does not appear to be of any value.

Sample 89. Weathered Schist

The sample was collected from a road cut on State Highway No. 48, 11.6 miles northwest of Ashland. There is an exposure of 100 feet. The clay is variegated in black, yellow and red. It is soft and weathered, and slakes well in water. It is a residual clay from a weathered hornblende schist. It contains illite and kaolinite.

The chemical analysis of the weathered schist is as follows:

Ignition loss	14.27%
SiO_2	40.30
Al_2O_3	22.90
Fe_2O_3	17.40
TiO_2	1.75
CaO	0.15
MgO	1.54
Alkalies as Na_2O	0.80
	99.11

Geological formation: Talladega

Working properties: Fair, it does not mix particularly well with water, but it can be extruded readily from the machine.

Drying behavior:

Linear drying shrinkage	4.7%
Volume drying shrinkage	13.4

Pore water	39.0
Shrinkage water	17.5
Water of plasticity	56.5
Drying defects	None noted

Transverse strength: 192 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	55.7	13.4	4.7	Deep buff
06	52.5	18.15	6.5	Deep buff
04	-----	-----	-----	------------------
02	48.0	26.0	9.5	Light brownish red
1	48.5	25.5	9.3	Light brownish red
3	46.9	28.05	10.4	Light brownish red
5	45.6	29.8	11.1	Light brownish red
7	45.2	30.2	11.3	Dark red
9	41.5	34.9	13.3	Reddish brown
11	31.1	43.5	17.3	Reddish black
13	0.7	52.4	21.9	Gun metal

P.C.E.: Cone 14

This is a remarkable clay in that it has a high porosity over a wide temperature range, and does not tend to overfire until above cone 13. The dry strength is sufficient for easy handling. The colors of the fired pieces are good.

Sample 90. Phyllite

The sample was obtained along State Highway No. 48 between Ashland and Talladega, and 15.3 miles northwest of Ashland. There is a 30-foot exposure. It is a soft weathered phyllite schist, yellow in color. It slakes readily in water.

Geological formation: Talladega

Working properties: It was not plastic enough to be extruded from the machine.

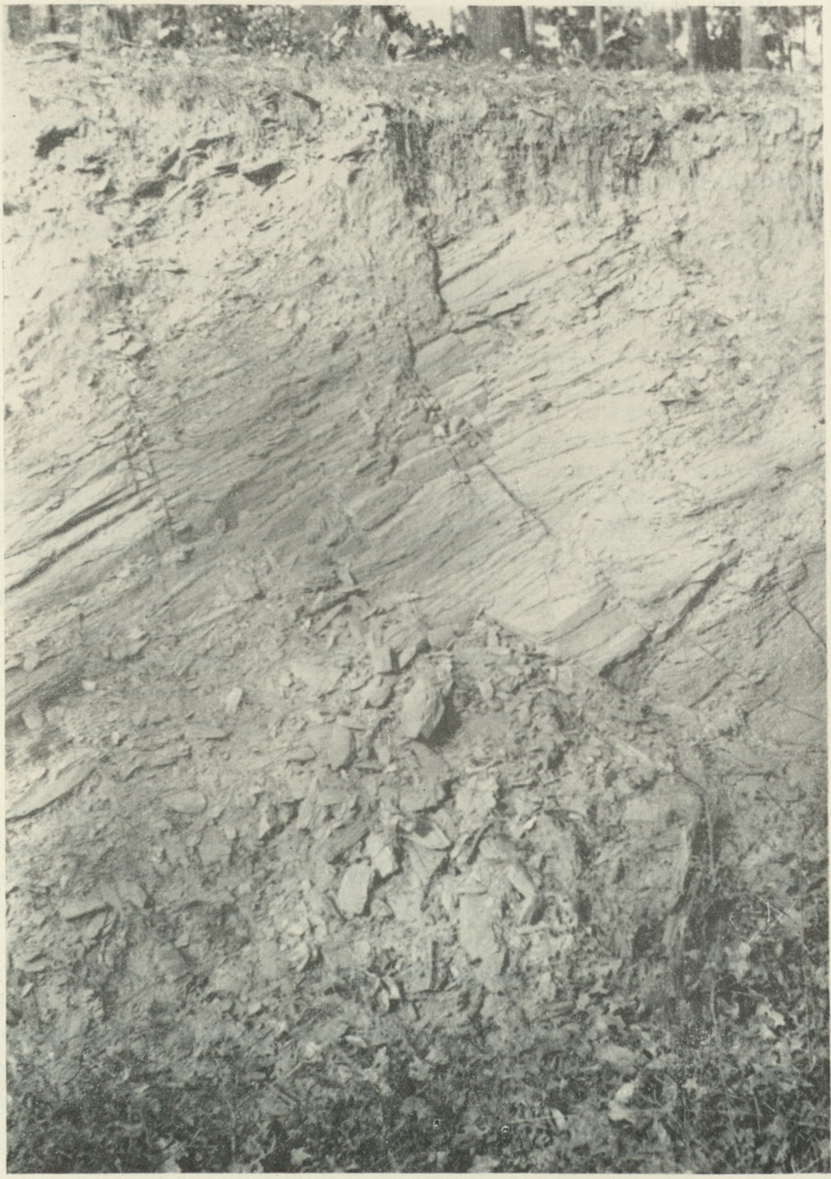


Fig. 14.—Talladega phyllite 15.3 miles northwest of Ashland on Alabama Highway 48 to Talladega, Talladega County. Sample No. 90.

P.C.E.: Cone 13-14

The material does not appear to be of value.

TUSCALOOSA COUNTY

Sample 22. Shale

The sample was obtained from a road cut on the west side of U. S. Highway No. 43 about 12.5 miles north of Northport in the south bank of Binion Creek and one-half mile north of locality No. 23. The shale is yellow in color due to weathering. It has a fissile structure, is sandy, and slakes slightly in water.

Geological formation: Pottsville

Working properties: Poor, as it was sandy and tended to crack.

Drying behavior:

Linear drying shrinkage	2.5%
Volume drying shrinkage	7.1
Pore water	16.9
Shrinkage water	3.7
Water of plasticity	20.6
Drying defects	None noted

Transverse strength: 242 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	34.7	0.6	0.2	Light salmon
06	33.65	3.3	1.1	Salmon
04	27.9	9.3	3.3	Light brownish red
02	25.6	11.5	4.0	Light brownish red
1	23.0	14.2	5.0	Light brownish red
3	19.1	17.35	6.2	Brownish red
5	15.8	20.6	7.5	Dark brownish red

7	11.35	23.35	8.6	Reddish brown
9	10.1	22.8	8.3	Chocolate
11	20.8	11.0	3.9	Gray

P.C.E.: Cone 14

The shale started to overfire at cone 9, but this did not become serious until cone 11 was reached. The shale never reached a low porosity and would be of no value for the manufacture of vitrified clay products. The color after firing was good.

Sample 23. Shale

This is a sample of shale taken from a road cut on the west side of U. S. Highway No. 43 about 12 miles north of Northport, and one-half mile south of Binion Creek. The bluff of this shale is 2.3 miles north of the locality of sample No. 24. This is a hard sandy shale which did not slake in water.

Geological formation: Pottsville

P.C.E.: Cone 13

The shale was not satisfactory and would not work through the machine.

Sample 24. Shale

The shale is located in a road cut on U. S. Highway No. 43 about 9 miles north of Northport on the west side of the road. The sample was taken from the upper half of the bluff about 3.3 miles south of Binion Creek. It is a yellowish-brown sandy shale. and did not slake well in water.

Geological formation: Pottsville

Working properties: Good

Drying behavior:

Linear drying shrinkage	3.1%
Volume drying shrinkage	8.8
Pore water	20.6

Shrinkage water	3.9
Water of plasticity	24.5
Drying defects	None noted

Transverse strength: 232 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	37.6	0.1	0.3	Light salmon
06	36.0	3.1	1.0	Salmon
04	32.0	7.9	2.7	Salmon
02	29.3	11.2	3.9	Salmon
1	27.5	13.0	4.5	Salmon
3	23.7	17.1	6.1	Light brownish red
5	22.9	17.8	6.3	Light brownish red
7	16.9	23.0	8.3	Dark brownish red
9	8.7	28.4	10.5	Chocolate
11	9.5	26.2	9.6	Dark chocolate

P.C.E.: Cone 14

The shale is a sandy type and never reached a low porosity in firing, consequently, it cannot be used for making vitrified shale products. It would be satisfactory for common brick. It is easily oxidized due to its porous nature. The transverse strength is satisfactory, and the fired color is fairly good.

Sample 25. Shale

The sample was taken from the same locality as No. 24, but is from the lower part of the bluff. It is a hard fissile shale, and is brown in color. It slaked slightly in water.

Geological formation: Pottsville

Working behavior: It worked well through the machine.

Drying behavior:

Linear drying shrinkage	3.0%
Volume drying shrinkage	8.5
Pore water	18.3
Shrinkage water	4.6
Water of plasticity	22.9
Drying defects	None noted

Transverse strength: 366 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	34.8	2.8	0.90	Buff
06	29.0	10.7	3.7	Light salmon
04	23.0	17.2	6.1	Salmon
02	17.8	21.4	7.8	Light brownish red
1	7.1	28.7	10.7	Brownish red
3	0.15	31.0	11.7	Brownish red
5	0.4	31.5	11.9	Deep brownish red
7	0.15	30.9	11.6	Very deep brownish red
9	15.5	12.5	4.4	Chocolate

P.C.E.: Cone 13

The shale has a long vitrification range, and should be satisfactory for the manufacture of vitrified structural shale products. It tends to overfire at cone 9. It has a good dry strength, and fires to excellent colors.

Sample 26. Shale

This is shale from a road cut on the east side of U. S. Highway No. 43, 9.3 miles north of Binion Creek and 7 miles north of Samantha. The bed is about 10 feet thick. It is a hard platy shale, with a brown color, and did not slake in water.

Geological formation: Pottsville

Working properties: It was not plastic enough to be extruded from the auger machine.

P.C.E.: Cone 15-16

The shale might work satisfactorily with the dry press method of making products. It has a good color when fired.

Sample 27. Shale

The shale is in the east side of a road cut where it has been quarried, 7.8 miles north of Samantha and 11 miles south of Bankston on U. S. Highway No. 43. This is a sample of the gray shale overlying the black shale (Sample 29). The gray shale has a thickness of 15 feet from the top of the black shale to the top of the cut. The clay slakes slightly in water.

Geological formation: Pottsville

Working properties: Very good

Drying behavior:

Linear drying shrinkage	3.5%
Volume drying shrinkage	10.1
Pore water	19.9
Shrinkage water	5.6
Water of plasticity	25.5
Drying defects	None noted

Transverse strength: 306 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	34.3	7.0	2.4	Buff
06	31.3	10.6	3.7	Light salmon

04	19.55	22.45	8.1	Salmon
02	13.8	27.25	10.1	Light brownish red
1	0.15	33.8	12.9	Dark brownish red
3	0.0	34.9	13.4	Dark brownish red
5	0.3	34.6	13.2	Dark brownish red
7	0.0	32.4	12.3	Very dark brownish red
9	0.35	16.5	5.9	Chocolate
11	3.0	15.2	5.4	Gun metal

P.C.E.: Cone 14

The clay has a good vitrification range, and could be used for the manufacture of vitreous clay products. It would require some care in oxidation. The colors of the fired pieces are satisfactory.

Sample 29. Shale

This is shale from the same locality as number 27. The sample is from a bed of black shale about 5 feet thick to the bottom of the road cut, underlying the gray shale. It slaked slightly in water.

Geological formation: Pottsville

Working properties: Very good

Drying behavior:

Linear drying shrinkage	4.5%
Volume drying shrinkage	12.8
Pore water	16.8
Shrinkage water	6.5
Water of plasticity	23.3
Drying defects	None noted

Transverse strength: 383 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	32.4	4.6	1.6	Buff
06	24.2	14.8	5.2	Salmon
04	10.9	26.3	9.7	Brownish red
02	0.75	29.9	11.2	Dark brownish red
1	0.4	29.8	11.2	Dark brownish red
3	0.1	27.3	10.1	Dark brownish red
5	1.8	17.1	6.1	Very dark brownish red

P.C.E.: Cone 12

The shale overfired at cone 5, which is very low. It could be used for the manufacture of shale products, but there is not enough of it. It is rather difficult to oxidize and contains considerable lime. The fired bars show a white scum.

Sample 102. Shale

The sample was selected from a road cut 4.3 miles south of the Tuscaloosa-Fayette County line on U. S. Highway No. 43. There is an exposure of 25 feet. The sample was selected from the lower portion of the deposit. The top of the deposit is very sandy. This is a fissile carbonaceous shale which breaks into small pieces. It did not slake in water.

Geological formation: Pottsville

Working properties: Good

Drying behavior:

Linear drying shrinkage	3.2%
Volume drying shrinkage	9.2
Pore water	14.4
Shrinkage water	4.9
Water of plasticity	19.3
Drying defects	None noted

Transverse strength: 298 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	28.8	7.05	2.5	Salmon
06	15.9	20.0	7.2	Salmon
04	6.1	26.4	9.7	Brownish red
02	0.35	28.45	10.6	Brownish red
1	0.20	27.7	10.2	Brownish red
3	0.25	24.9	9.1	Brownish red
5	7.5	2.0	0.7	Brownish red

P.C.E.: Cone 7-8

This shale showed a considerable amount of lime, but it is evidently not present as large pieces of limestone. It gave a test for sulfates. The shale vitrifies at a very low temperature and is plastic. The fired color is very good. It may be useful for making low fired ware where a good color is desired. The test pieces had a very good red color when fired at cones 02, 1, and 3.

WALKER COUNTY

Sample 4. Fire Clay

The sample was obtained from the Alabama Clay Products Company at Bessemer and was a mixed sample of Pottsville clay shipped from Cordova, Alabama. A large tonnage of this clay is used in the manufacture of ladle brick. It is gray in color, and shows typical "slickensides", characteristic of many of the under clays from coal seams. It slakes in to angular fragments.

Geological formation: Pottsville

Working properties: Fair

Drying properties:

Linear drying shrinkage	5.1%
Volume drying shrinkage	14.6
Pore water	9.9
Shrinkage water	7.0
Water of plasticity	16.9
Drying defects	None noted

Transverse strength: 500 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	25.7	6.5	2.2	Cream through tans to light gray at cone 11
06	23.5	8.85	3.0	
04	19.4	13.4	4.7	
02	17.1	15.15	5.3	
1	16.4	14.8	5.2	
3	13.35	16.4	5.8	
5	12.6	16.6	5.9	
7	9.6	17.6	6.2	
9	7.3	18.5	6.6	
11	7.8	17.6	6.2	
13	7.1	14.0	4.9	Dark gray

P.C.E.: Cone 28

The clay may be classed as an open firing clay because it never approached zero porosity. The clay has a tendency to bloat at cone 13, but this is not serious. It does not readily oxidize, but the oxidation characteristics are not a serious detriment to its use. When used alone, it is suitable for the manufacture of ladle brick. The P.C.E. is comparatively high for the fire clays of the Pottsville formation and it can be mixed with high grade clays for the manufacture of refractories. It has a good dry strength and consequently is a good bond clay. The fired colors are satisfactory.

Sample 11. Fire clay

The fire clay underlies a coal seam on the property of the Stephenson Brick Company at Cordova, Alabama. It is blue-black in color and slakes to some extent.

Geological formation: Pottsville

Working properties: Very satisfactory

Drying behavior:

Linear drying shrinkage	3.8%
Volume drying shrinkage	10.9
Pore water	12.4
Shrinkage water	5.7
Water of plasticity	18.1
Drying defects	It is necessary to dry with some care to prevent cracking. This has been successfully accomplished in the plant.

Transverse strength: 529 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	29.1	3.6	1.3	Light cream through tans to gray at cone 9
06	27.3	5.9	2.1	
04	26.55	7.2	2.5	
02	23.1	10.7	3.7	
1	21.2	11.5	4.0	
3	20.4	12.3	4.3	
5	19.2	13.8	4.9	
7	16.4	15.05	5.4	
9	13.6	15.4	5.4	Gray
11	10.1	16.9	6.0	Gray
13	15.8	9.3	3.2	Gray

P.C.E.: Cone 20. Other samples have had a P.C.E. of cone 23.

This clay has been used for a number of years for the manufacture of buff and gray face brick as well as for glazed brick. It is well suited for the manufacture of many structural clay products when a gray or buff color is desired. It is not readily oxidized, but is fired successfully in commercial kilns. It is characterized by a very high transverse strength. It never reached a low porosity in firing. Both the drying and firing shrinkages are moderate.

Sample 96. Shale

The sample was taken from the side of the road on U. S. Highway 78 southeast of Jasper near the city limits close to the railroad. There is an exposure of 30 feet of shale. The shale is yellow-brown in color due to weathering. It slakes well in water.

Geological formation: Pottsville shale

Working properties: Very good

Drying behavior:

Linear drying shrinkage	4.1%
Volume drying shrinkage	11.8
Pore water	15.4
Shrinkage water	6.1
Water of plasticity	21.6
Drying defects	None noted

Transverse strength: 394 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	51.3	6.9	2.4	Buff
06	25.2	13.1	4.6	Salmon
04	19.5	19.3	6.9	Salmon
02	0.6	28.9	10.7	Light brownish red

1	0.15	29.2	10.9	Brownish red
3	0.30	29.7	11.1	Brownish red
5	0.00	29.3	11.1	Brownish red
7	0.15	26.7	9.9	Brownish red
9	13.7	12.7	4.4	Reddish brown

P.C.E.: Cone 13

The shale has good working properties and very high dry strength. It has a long firing range, and can be used for making vitrified products. There is a rather sudden drop in porosity and an increase in shrinkage between cone 04 and 02. Some care would be necessary in this part of the firing range. The shale is easily oxidized. This material may be valuable because it is a fairly high grade, and because it is near Jasper. The colors after firing are very good.

Sample 97. Shale

The sample was taken from a road cut on the paved road leading from U. S. Highway No. 78 to Cordova. The location of the sample is 1.6 miles south of the junction of the two roads and there is about 20 feet exposed. This is hard carbonaceous shale, gray in color, which slaked fairly well.

Geological formation: Pottsville shale

Working properties: Good

Drying behavior:

Linear drying shrinkage	3.6%
Volume drying shrinkage	10.4
Pore water	16.0
Shrinkage water	5.4
Water of plasticity	21.4
Drying defects	None noted

Transverse strength: 380 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	51.0	7.1	2.4	Buff
06	21.6	16.5	5.8	Salmon
04	15.2	22.6	8.2	Deep salmon
02	0.2	30.9	11.6	Brownish red
1	0.15	30.7	11.5	Brownish red
3	0.15	29.7	11.1	Brownish red
5	0.3	26.2	9.6	Brownish red
7	2.5	13.9	4.9	Brownish red

P.C.E.: Cone 14

This shale is quite similar to sample No. 96, and could be used for the same purposes.

Sample 98. Shale

The sample was obtained about 1 mile west of Cordova on the road to Parrish, Alabama. There is an exposure of about 80 feet. This is a hard platy carbonaceous shale which will not slake in water.

Geological formation: Pottsville

Working properties: It is non-plastic, and could not be formed into test pieces.

P.C.E.: Cone 10. The cones tend to bloat and the P.C.E. determination is not accurate.

There is a very large amount of this shale available. It is not satisfactory for making ceramic ware, but it might be used for making a light-weight concrete aggregate.

WINSTON COUNTY

Sample 94. Shale

The sample was taken from a road cut between Double Springs and Haleyville 9 miles from Haleyville on State Highway No. 5. There is an exposure of 14 feet. This is a weathered shale, yellow to brown in color. It slakes readily to a mud.

Geological formation: Lower Pottsville

Working properties: Very good

Drying behavior:

Linear drying shrinkage	4.8%
Volume drying shrinkage	13.8
Pore water	16.6
Shrinkage water	7.2
Water of plasticity	23.8
Drying defects	None noted

Transverse strength: 334 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	33.4	3.1	1.0	Buff
06	29.7	8.1	2.8	Reddish buff
02	20.0	19.0	6.8	Salmon
1	18.7	19.9	7.1	Light brownish red
3	15.15	22.5	8.1	Light brownish red
5	12.1	23.9	8.7	Light brownish red
7	3.1	26.6	9.8	Reddish brown
9	1.6	26.4	9.7	Reddish brown
11	15.0	15.3	5.4	Yellow gray

P.C.E.: Cone 15-16

The above is a good shale. It has a fairly good firing range and could be used for high grade products. Its dry strength is very good. The color of the fired bars is fair.

Sample 95. Shale

The sample was taken from a road cut 7.5 miles south of Double Springs on State Highway No. 5 where there is an exposure of 12 feet. This is a weathered shale, yellow-brown in color, which slakes in water.

Geological formation: Pottsville

Working properties: Good

Drying behavior:

Linear drying shrinkage	3.8%
Volume drying shrinkage	10.9
Pore water	19.4
Shrinkage water	6.1
Water of plasticity	25.5
Drying defects	None noted

Transverse strength: 151 pounds per square inch

Firing behavior:

Cone	Porosity %	Volume Shrinkage %	Linear Shrinkage %	Color
08	37.25	2.7	0.9	Buff
06	34.00	7.7	2.6	Buff
04	30.5	12.5	4.4	Salmon
02	24.1	19.2	6.9	Light brownish red
1	20.95	21.95	8.0	Light brownish red
3	18.65	24.0	8.7	Light brownish red
5	16.7	25.35	9.3	Light brownish red
7	12.9	28.0	10.4	Dark brownish red
9	2.0	30.4	11.4	Chocolate

P.C.E.: Cone 15-16

This shale is similar to sample No. 94 except that its dry strength is not as satisfactory. It should be satisfactory for most ceramic structural clay products.

SUMMARY OF RESULTS

The tests of the shales show that some of the deposits which are not being utilized at present are as good or better than those from which material is mined for commercial production of ceramic products. Other deposits have peculiar properties and some may be suited for the manufacture of products which are not made at the present time in Alabama.

Table 4 gives a summary of present and suggested uses for the shales and fire-clays. It must be realized however, that the tests were made in the laboratory and that it is frequently difficult to translate laboratory practice into plant production.

Table 4. Present and suggested uses of shales and fire-clays tested.

Number	Use	Page
1.	In use for the manufacture of brick and tile	75
2.	Light-weight aggregate	76
3.	In use for the manufacture of refractories	78
4.	In use for the manufacture of brick and tile	142
5.	In use for the manufacture of refractories	79
6.	In use for the manufacture of common and face brick	80
7.	In use for the manufacture of roofing tile	82
8.	In use for the manufacture of face and common brick	83
9.	In use with other clays for the manufacture of sewer pipe	44
10.	In use with other clays for the manufacture of sewer pipe	84
11.	In use for making buff, gray and glazed brick and tile	144
12.	Common brick	98
13.	For silica cement and daubing clay	99
14.	Common brick	68
15.	Siliceous porous refractories and daubing clay	57
16.	Sewer pipe Low grade fire-clay. Buff firing shale	69
17.	Vitrified structural clay products	103
18.	Common brick	85
19.	Vitrified structural clay products	86
20.	Common brick	87
21.	Sewer pipe, structural clay products	88
22.	Common brick and tile	135
23.	No industrial use indicated	136
24.	Common brick	136
25.	Vitrified structural clay products	137
26.	No industrial use indicated	138
27.	Vitrified clay products	139
28.	Common brick	65

Number	Use	Page
29.	Structural clay products. The deposit is small	140
30.	Structural clay products including sewer pipe	60
31.	Vitrified structural clay products	90
32.	Has possibilities as a glaze	91
33.	Structural clay products	61
34.	Light-weight aggregate. Common brick	115
35.	Common brick	117
36.	Common brick and tile	118
37.	Light-weight aggregate	119
38.	Vitrified structural clay products	120
39.	Vitrified structural clay products	91
40.	Vitrified structural clay products	93
41.	Light-weight aggregate	43
42.	Floor tile, red pottery. Was used for brick	123
43.	Floor tile, red pottery. Was used for brick	124
44.	Light-weight aggregate. Common brick	125
45.	No industrial use indicated	126
46.	Light-weight aggregate. Common brick	126
47.	Vitrified structural clay products	94
48.	Structural clay products	95
49.	Structural clay products	96
50.	No industrial use indicated	97
51.	No industrial use indicated	106
52.	Structural clay products	106
53.	Vitrified structural clay products	107
54.	Light-weight aggregate	108
55.	No industrial use indicated	109
56.	In use for brick, chimney block, acid rings	109
57.	In use for brick, chimney block, acid rings	112
58.	Sewer pipe and structural clay products	113
59.	No value as it is a limey clay	114
60.	Structural clay products, particularly common brick	70
61.	Structural clay products, particularly common brick	71
62.	Common brick	72
63.	Structural clay products	73
64.	No industrial use indicated	62
65.	Common brick	63
66.	Has been used for making brick	64
67.	No industrial use indicated	45
68.	Has been used for the manufacture of brick	45
69.	Probably of no value	46
70.	Common brick	47
71.	Light-weight aggregate	100
72.	Low fusion point bond clay	101
73.	Light-weight aggregate	102
74.	No industrial use indicated	52
75.	Bond clay but vitrifies at a low temperature	53
76.	Light-weight aggregate	127

Number	Use	Page
77.	Structural clay products. Low dry strength	128
78.	No industrial use indicated	129
79.	No industrial use indicated	129
80.	No industrial use indicated	131
81.	No industrial use indicated	131
82.	No industrial use indicated	48
83.	Structural clay products, Low dry strength	50
84.	No industrial use indicated	54
85.	Common brick. Low dry strength	55
86.	No industrial use indicated	56
87.	No industrial use indicated	56
88.	No industrial use indicated	56
89.	Light-weight brick. These have insulating properties	132
90.	No industrial use indicated	133
91.	No industrial use indicated	51
92.	No industrial use indicated	52
93.	Structural clay products	105
94.	Structural clay products	148
95.	Structural clay products	149
96.	Vitrified structural clay products	145
97.	Vitrified structural clay products	146
98.	Light-weight aggregate	147
99.	Floor tile, pottery and brick	67
100.	No industrial use indicated	43
101.	No industrial use indicated	43
102.	Red pottery, flower pots, floor tile, brick	141
103.	Silica cements or daubing clay	58
104.	No industrial use indicated	59

INDEX LIST OF SAMPLES TESTED

Sample No.	Formation	Material	County	Page
1.	Pottsville	Shale	Jefferson	75
2.	Pottsville	Shale	Jefferson	76
3.	Pottsville	Fire clay	Jefferson	78
4.	Pottsville	Fire clay	Walker	142
5.	Pottsville	Fire clay	Jefferson	79
6.	Pottsville	Shale	Jefferson	80
7.	Pottsville	Shale	Jefferson	82
8.	Pottsville	Shale	Jefferson	83
9.	Pottsville	Fire clay	Blount	44
10.	Pottsville	Shale	Jefferson	84
11.	Pottsville	Fire clay	Walker	144
12.	Pottsville	Shale	Lawrence	98
13.	Gasper	Shale	Lawrence	99

INDEX LIST OF SAMPLES TESTED—Continued

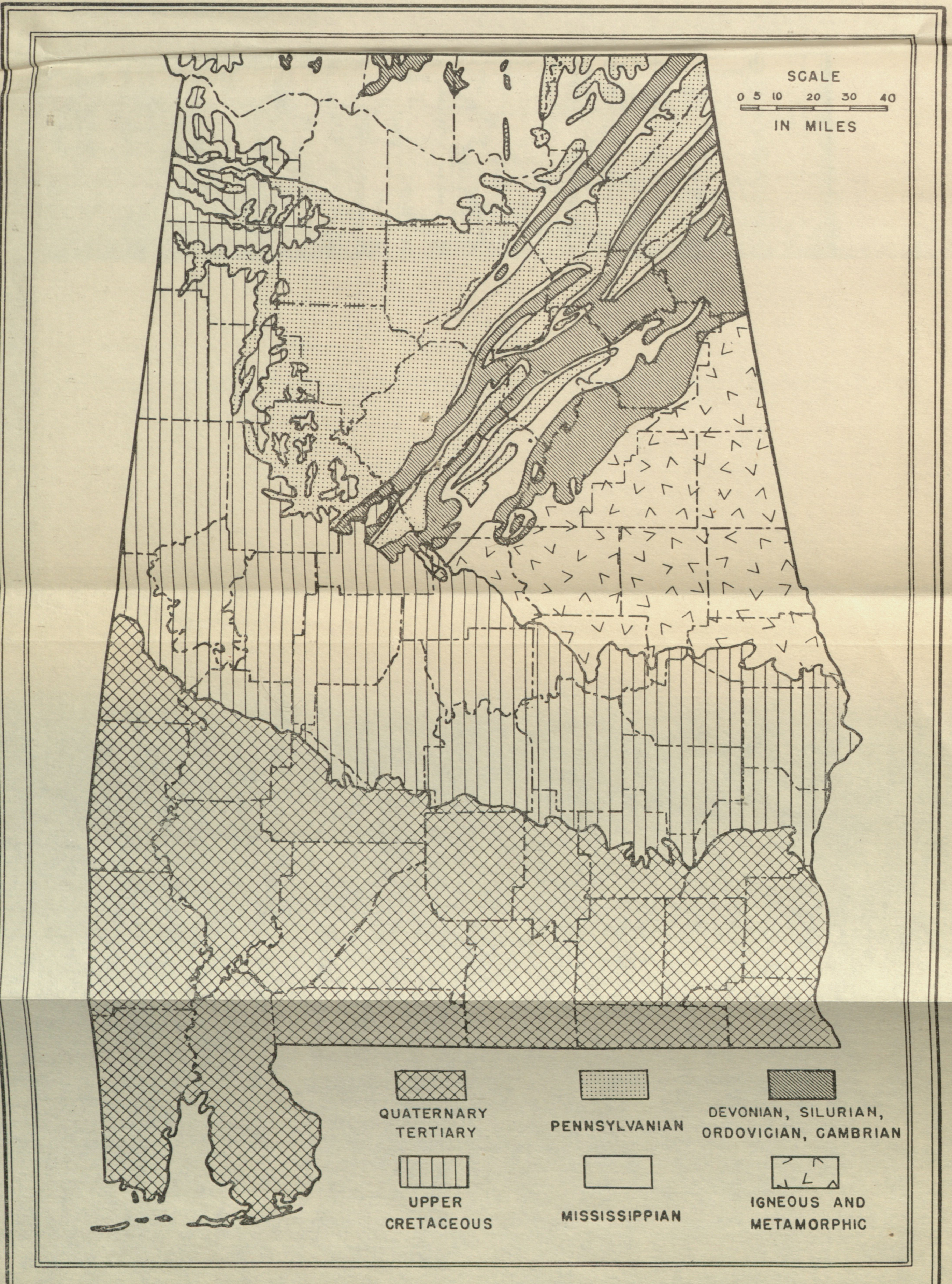
Sample No.	Formation	Material	County	Page
14.	Pottsville	Shale	Franklin	68
15.	Tuscaloosa	Fire clay	Colbert	57
16.	Pottsville	Shale	Franklin	69
17.	Pottsville	Shale	Marion	103
18.	Pottsville	Shale	Jefferson	85
19.	Pottsville	Shale	Jefferson	86
20.	Pottsville	Shale	Jefferson	87
21.	Pottsville	Impure fire clay	Jefferson	88
22.	Pottsville	Shale	Tuscaloosa	135
23.	Pottsville	Shale	Tuscaloosa	136
24.	Pottsville	Shale	Tuscaloosa	136
25.	Pottsville	Shale	Tuscaloosa	137
26.	Pottsville	Shale	Tuscaloosa	138
27.	Pottsville	Shale	Tuscaloosa	139
28.	Pottsville	Shale	Fayette	65
29.	Pottsville	Shale	Tuscaloosa	140
30.	Lower Pottsville	Shale	Cullman	60
31.	Pottsville	Shale	Jefferson	90
32.	Pottsville	Shale	Jefferson	91
33.	Lower Pottsville	Shale	Cullman	61
34.	Floyd	Shale	Shelby	115
35.	Waxahatchee (Talladega)	Shale	Shelby	117
36.	Waxahatchee (Talladega)	Shale	Shelby	118
37.	Pottsville	Shale	Shelby	119
38.	Pottsville	Shale	Shelby	120
39.	Pottsville	Shale	Jefferson	91
40.	Pottsville	Shale	Jefferson	93
41.	Pottsville	Shale	Bibb	43
42.	Conasauga	Clay	Shelby	123
43.	Conasauga	Clay	Shelby	124
44.	Rome ("Montevallo")	Shale	Shelby	125
45.	Rome ("Montevallo")	Shale	Shelby	126
46.	Rome ("Montevallo")	Shale	Shelby	126
47.	Pottsville	Shale	Jefferson	94
48.	Pottsville	Shale	Jefferson	95
49.	Pottsville	Shale	Jefferson	96
50.	Pottsville	Shale	Jefferson	97
51.	Floyd	Shale	St. Clair	106
52.	Parkwood	Shale	St. Clair	106
53.	Lower Pottsville	Shale	St. Clair	107
54.	Pottsville	Shale	St. Clair	108
55.	Floyd	Shale	St. Clair	109
56.	Pottsville	Shale	St. Clair	109
57.	Pottsville	Shale	St. Clair	112
58.	Floyd	Shale	St. Clair	113

INDEX LIST OF SAMPLES TESTED—Continued

Sample No.	Formation	Material	County	Page
59.	Conasauga	Shale	St. Clair	114
60.	Red Mountain	Shale	Jackson	70
61.	Gasper	Shale	Jackson	71
62.	Gasper	Shale	Jackson	72
63.	Pottsville	Shale	Jackson	73
64.	Red Mountain	Shale	DeKalb	62
65.	Red Mountain	Shale	DeKalb	63
66.	Pottsville	Shale	Etowah	64
67.	Conasauga	Shale	Calhoun	45
68.	Rome ("Montevallo")	Shale	Calhoun	45
69.	Rome ("Montevallo")	Shale	Calhoun	46
70.	Rome ("Montevallo")	Shale	Calhoun	47
71.	Oak Hill beds, Naheola	Shale or bedded clay	Marengo	100
72.	Nanafalia	Shale or bedded clay	Marengo	101
73.	Tuscahoma	Shale or bedded clay	Marengo	102
74.	Hatchetigbee	Shale or bedded clay	Clarke	52
75.	Hatchetigbee	Shale or bedded clay	Clarke	53
76.	Floyd	Shale	Shelby	127
77.	Waxahatchee (Talladega)	Shale	Shelby	128
78.	Floyd	Shale	Shelby	129
79.	Talladega	Phyllite	Talladega	129
80.	Talladega	Phyllite	Talladega	131
81.	Talladega	Phyllite	Talladega	131
82.	Weisner	Shale	Cherokee	48
83	Weisner	Weathered schist	Cherokee	50
84.	Weisner	Shale or bedded sandy clay	Cleburne	54
85.	Weisner	Shale or sandy bedded clay	Cleburne	55
86.	Talladega	Phyllite	Cleburne	56
87.	Hillabee schist	Chlorite schist	Cleburne	56
88.	Talladega	Schist	Cleburne	56
89.	Talladega	Weathered schist	Talladega	132
90.	Talladega	Phyllite	Talladega	133
91.	Waxahatchee (Talladega)	Phyllite	Chilton	51
92.	Talladega	Schist	Chilton	52
93.	Lower Pottsville	Shale	Marion	105
94.	Lower Pottsville	Shale	Walker	148
95.	Pottsville	Shale	Walker	149
96.	Pottsville	Shale	Walker	145

INDEX LIST OF SAMPLES TESTED—Continued

Sample No.	Formation	Material	County	Page
97.	Pottsville	Shale	Walker	146
98.	Pottsville	Shale	Walker	147
99.	Pottsville	Shale	Fayette	67
100.	Tuscaloosa	Bedded clay	Bibb	43
101.	Tuscaloosa	Bedded clay	Bibb	43
102.	Pottsville	Shale	Tuscaloosa	141
103.	Tuscaloosa	Bedded clay	Colbert	58
104.	Tuscumbia limestone	Shale	Colbert	59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IN MILES
QUATERNARY TERTIARY
PENNSYLVANIAN
DEVONIAN, SILURIAN, ORDOVICIAN, CAMBRIAN
UPPER CRETACEOUS
MISSISSIPPIAN
IGNEOUS AND METAMORPHIC

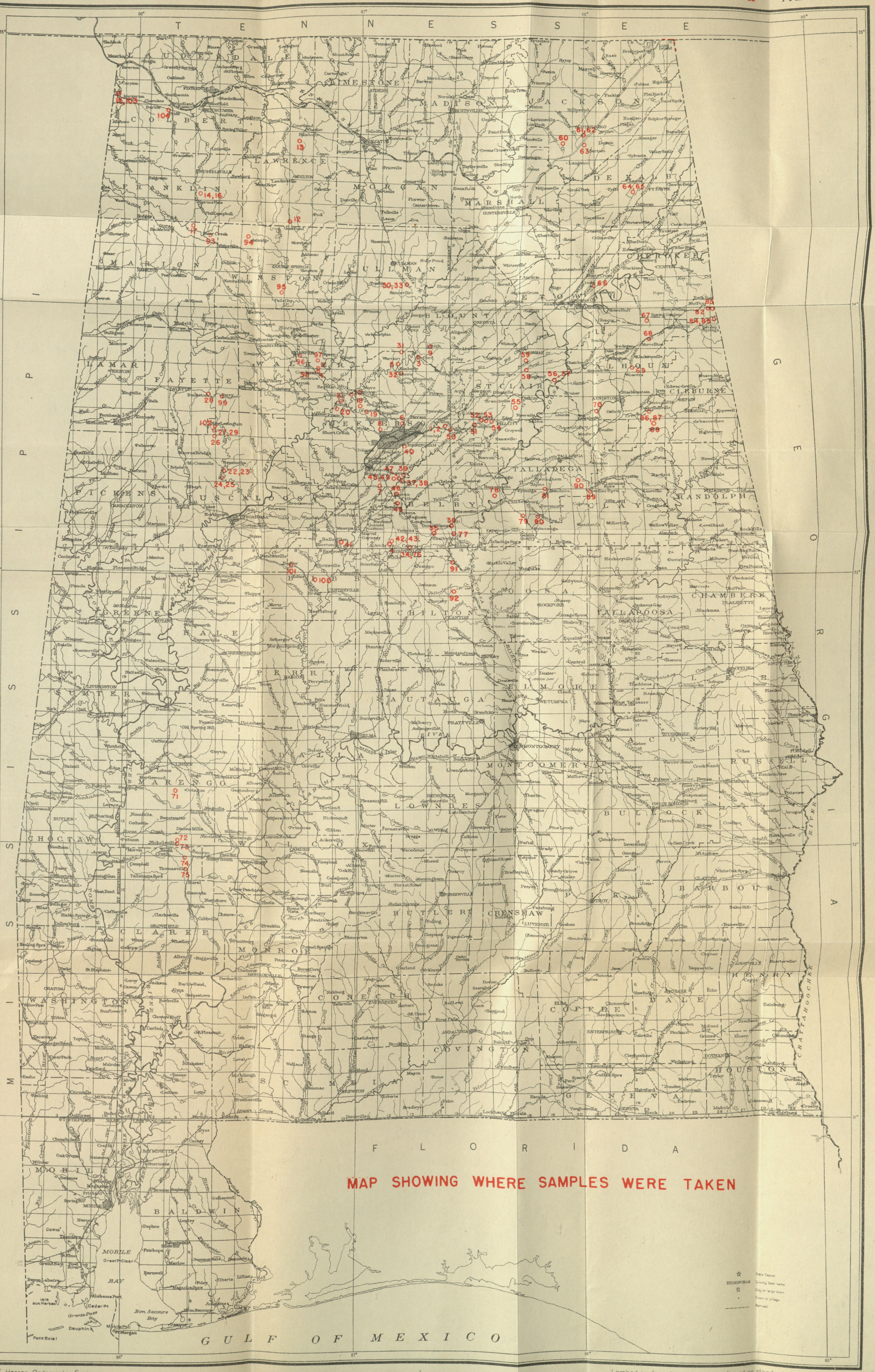
GEOLOGIC MAP OF ALABAMA

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GEOLOGICAL SURVEY OF ALABAMA

BULLETIN 55 PLATE II

ALABAMA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MISSISSIPPI
GEORGIA
FLORIDA
GULF OF MEXICO
LAUDERDALE
LIMESTONE
MADISON
JACKSON
COLBERT
LAWRENCE
MORGAN
MARSHALL
DEKALB
FRANKLIN
MARION
WINSTON
CULLMAN
ETOWAH
CHEROKEE
LAMAR
FAYETTE
WALKER
BLOUNT
ST. CLAIR
CALHOUN
CLEBURNE
PICKENS
TUSCALOOSA
JEFFERSON
SHELBY
TALLADEGA
CLAY
RANDOLPH
BIBB
COOSA
TALLAPOOSA
CHAMBERS
GREENE
HALE
CHILTON
SUMTER
PERRY
AUTAUGA
ELMORE
LEE
MARENGO
DALLAS
MONTGOMERY
MACON
RUSSELL
CHOCTAW
WILCOX
LOWNDES
BULLOCK
BARBOUR
CLARKE
MONROE
BUTLER
CRENSHAW
PIKE
WASHINGTON
CONECUH
COFFEE
DALE
HENRY
ESCAMBIA
COVINGTON
GENEVA
HOUSTON
MOBILE
BALDWIN
MOBILE BAY
Bon Secours Bay
BIRMINGHAM
MONTGOMERY
88°
87°
86°
85°
35°
34°
33°
32°
31°
State Capital
BIRMINGHAM County Seat name
City or large town
Town or village
Railroad

MAP SHOWING WHERE SAMPLES WERE TAKEN

. F. Hassan, Cartographic Engineer
Compiled in 1912, revised 1925

Scale $\frac{1}{1,000,000}$
10 0 10 20 30 40 Miles
10 0 10 20 30 40 50 Kilometers

Lambert conformal conic projection (based on standard parallels 33° and 45°)
North American datum
Edition of 1933